TDG FOREBAY FIXED MONITORING STATION REVIEW AND EVALUATION FOR LOWER SNAKE RIVER PROJECTS AND MCNARY DAM

(BI-OP MEASURE 132)

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For
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Executive Summary

Action 132 of the 2000 Biological Opinion requests that a systematic review and evaluation of the TDG fixed monitoring system (FMS) stations in the forebays of all the mainstem Columbia and Snake River dams. This effort should make recommendation regarding improvement of the system to meet design purpose such as relocation and/or repositioning as warranted. This study was conducted during the 2003 fish spill season at McNary Dam and the four Lower Snake River projects, Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, and Lower Granite Dam. The basic approach was to evaluate the general representativeness of the six forebay TDG fixed monitors, two at McNary and one at each of the other four projects. In addition, alternative monitor locations were evaluated and compared to the existing FMS station. The study included alternative stations near to the existing FMS station but deeper, 10 m versus 5 m for existing. Additional alternative sites were included in the releases on the draft tube deck, on the upstream navigation lock guide wall, and suspended from buoys upstream of the projects.

All of the project forebay FMS stations were problematic in that each experienced thermally induced TDG pressure spikes during the test period. Some experienced spikes exceeding 5 % saturation fluctuation on a daily basis. This phenomenon is due to near field hydrodynamics coupled with vertical thermal gradients in the water column. Those monitors that are located on or near the upstream face of the powerhouse can impacted by the down welling of the warm surface waters which result in the ambiguous and none representative spiking of the TDG. The more significant occurrences were identified for McNary and Lower Granite dams. These sites also resulted is a relatively high number of exceedances of the water quality standard for TDG for the study period. The data suggests the fixed monitor instruments can often report TDG values that are not representative of the forebay waters and may not meet the requirements or purpose for the water quality station as described in the introduction.

The primary recommendations for improving the forebay FMS operation and representativeness are twofold. The first is to relocate each instrument to an area just upstream of the project not affected by down welling surface waters. This first choice is the upstream tip of the navigation lock guide wall or any other floating structure which does not impact flows near the instrument. Note that the Lower Granite FMS station is already positioned upstream. The second recommendation is to position each instrument at 12-15 m. This would be adequate to avoid thermal responses in the TDG pressure readings brought about a general deepening of the warm surface layer. The water temperature for the selected depth strata should approximate the average water column.

The recommendations from this study are consistent across all stations and should result in minor impacts on future operation. They will result in more representative data that should improve uses such as project management for TDG as well as water quality compliance evaluations. These changes will improve the stations ability to achieve all design purposes mentioned in the introduction of this report.

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Introduction

The Corps of Engineers (COE) operates several hydropower projects as part of the water resources infrastructure in the Columbia River Basin. These dams, reservoirs, and associated modifications to the water resources in the basin impact aquatic habitat and fisheries resources across the entire basin. Of particular concern is hyper-aeration of the water flowing through the dam spillways, which can lead to gas bubble disease in fish and other biota. Extensive water quality monitoring conducted to better understand the fundamental nature of dissolved gas loading and dynamics as a function of hydropower system operation has been ongoing since 1984 by the COE.

The management of Columbia and Snake River total dissolved gas pressures associated with project operation using the fixed water quality monitoring system is often unevenly applied at Corps of Engineer mainstem dams. The monitor measures are discrete in time and space normally on hour intervals but at only one depth and lateral location. These monitors can be non-representative of water quality conditions due to spatial and temporal gradients in quality conditions and near project hydrodynamic phenomenon.

In general, the water quality fixed monitoring stations, which measure and report TDG, water temperature, dissolved oxygen, and instrument depth, are designed for the following purposes.

- To provide river operations and fisheries managers with synthesized and relevant information needed to control dissolved gas supersaturation in the river system on a real time basis
- To determine how project releases affect downstream water quality and aquatic habitat relative to ESA Biological Opinion measures and CWA related state and tribal dissolved gas standards
- To identify long-term changes in basin wide dissolved gas saturation levels resulting from water management decisions (structural and operational) and/or natural processes, i.e., trend monitoring
- To provide data of known quality to enhance analytical and predictive capability of existing models/tools used to evaluate management objectives

Since 1994, two different types of stations based on location and function have been used to achieve the system purposes often with inconsistencies. The forebay instruments are located well downstream and generally in the forebay of the receiving pool project. The project forebay TDG monitors are intended to represent a mixed cross section in the river just upstream of the dam and can be a fair approximation of aquatic habitat as defined by TDG and water temperature in that area of the pool. This information is often applied to spill management practices for the upstream project plus it is applied to water quality

compliance monitoring as well. The tailwater instruments are located nearer to the project and generally in spillway releases downstream of aerated flow and prior to complete mixing with powerhouse releases. The tailwater location will often capture spill water average to peak TDG concentration.

Action 132 of the 2000 Biological Opinion states: "The action agencies shall develop a plan to conduct a systematic review and evaluation of the TDG fixed monitoring stations in the forebays of all the mainstem Columbia and Snake River dams (including the Camas/Washougal monitor). The evaluation plan shall be developed by February 2001 and included as part of the first annual water quality improvement plan. The Action Agencies shall conduct the evaluation and make changes in the location of fixed monitoring sites, as warranted, and in coordination with the Water Quality Team. It should be possible to make some modifications by the start of the 2001 spill season."

The McNary Dam and the four Lower Snake River project forebay fixed TDG monitor readings are often characterized with apparent thermally induced spikes in TDG pressures as is presented in Figures 1-6. This phenomenon can introduce considerable daily variability in the reported forebay TDG pressures and hence TDG management practices as related to upstream project operation and water quality compliance evaluations. The more extreme thermal related TDG spikes are present in Figures 1, 2, 3, and 6 for McNary (Oregon side), McNary (Washington side), Ice Harbor, and Lower Granite forebay measures. This phenomenon occurred on just a couple of instances for Lower Monumental Dam and Little Goose Dam. The largest pressure spikes of 5-6 % saturation (35-40 mm Hg) occurred routinely in the McNary forebay at station MCQO during 2003.

Study Design

A Multi-Year Plan to conduct review and evaluation of the COE forebay fixed monitoring stations (FMS) within the Walla Walla District including one site at each of the Lower Snake River plants -Lower Granite, Little Goose, Lower Monumental, Ice Harbor and two forebay monitors at McNary dam was initiated in 2003. The primary objective was to determine representative FMS station locations for the project of interest. These station locations must be capable of achieving the purposes as outlined in the introduction for the forebay FMS. Recommendations are to be made on alternative locations that will provide significant improvements in accomplishing the FMS purpose. The following tasks were conducted during FY 2003 in the Multi-Year Plan.

1. Review and analysis of existing data from the forebay fixed monitors for representativeness and anomalies in TDG and temperature
2. Evaluate and compare auxiliary sites at each project for performance and representativeness. Candidate sites were as follows
    a. One site in powerhouse release located on the after deck or draft tube deck for each project,

b. One site located approximately 1000-2500 ft upstream of each powerhouse and in the deepest part of the river cross-section,
c. Adjacent to the current fixed monitor in the forebay of the project but at an alternate depth,
d. When available on the upstream end of the navigation lock guide wall.

The second task required the investigation, planning, and placement of self-contained automated logging water quality instruments at each location. These instruments were operated intermittently during the period of May through July of 2003. Measurements for TDG, water temperature, and depth were taken on 15 minute intervals for the duration of the field study. Sixteen auxiliary instruments were needed for completion of the study. Calibration and maintenance of the equipment was conducted on a 2-4 week interval using regionally accepted methods (DGAS, 2000?).

Additional data utilized in this study include project operations and FMS data taken form the COE CROHMS database (WEB address) and thermal profile data for each project taken from the "Lower Snake River Temperature/Water Quality Studies 2002-2003" (CENWW, in progress). The project operations data including total discharge, spill discharge, and pool elevation was recorded on 1 hour intervals. The FMS station data include station location, TDG, water temperature, and depth collected on hourly intervals at approximately 5 m deep and then stored on the COE CROHMS database. The temperature profiles were collected on 15 minute intervals using remote automated logging instruments spaced at appropriate depth intervals throughout the water column in the deepest part of the forebay cross-section.

The alternate sampling station locations varied by each project. Figures 7-10 depict the sampling sites by project. These diagrams include both the added research sites as well as the existing FMS stations. The alternate stations are at 10 meters depth except for the draft tube instruments which were at 5 m. McNary Dam sample stations are presented in figure 7. In addition to the FMS stations MCPW, MCQO, and MCQW there were two additional TDG logging instruments, MCNFBFMSP1 and MCNFBFMSP2, located adjacent to the MCQO and MCQW. Station MCNFBBRZP1 was located approximately 400 m upstream of the south end of the powerhouse suspended from a Boats Restricted Zone (BRZ) buoy and on the Oregon side of the river, station. MCNFBBRZP2 located 400 m upstream of the north end of the project was only profiling and logging water temperature and not TDG. The draft tube deck instrument (MCNDTD) was located between unit 5 and 6 releases at 5 meters deep

The alternate TDG sampling station locations for Ice Harbor Dam are depicted in Figure 8. Station IHRFBFMS was located on the powerhouse upper deck adjacent to IHR. Station IHRFBNL (thermal profile only) was located on the end of the navigation lock forebay wing wall at 180 meters upstream of the north end of the spillway structure. Station IHRFBBRZ was suspended from a BRZ buoy 700 m upstream of the powerhouse. The IHRDTD station was positioned at the middle of the draft tube deck.

The alternate TDG sampling station locations for Lower Monumental Dam are depicted in Figure 9. Station LMNFBFMS was located on the powerhouse upper deck adjacent to LMN. Station LMNFBNL was located 225 m upstream of the structure on the end of the navigation lock guide wall. Station LMNFBBRZ was located on a BRZ buoy 530 m upstream of the spillway. The LMNDTD was positioned in the middle of the draft tube deck.

The alternate sampling station locations for Little Goose Dam are depicted in Figure 10. Station LGSFBFMS was located on the powerhouse upper deck adjacent to LGS. Station LGSFBNL was 125 m upstream of the powerhouse on the end of the navigation lock guide wall. Station LGSFBBRZ was positioned 560 m upstream of the middle of the powerhouse on a BRZ buoy. LGSDTD was positioned in the middle of the draft tube deck.

Figure 11 depicts the alternate TDG sampling station locations for Lower Granite Dam. Station LWGFBNL was positioned adjacent to the forebay routine monitor, LWG, on the end of the navigation lock guide wall. Station LWGFBBRZ was positioned 740 m upstream of the project and suspended from a BRZ buoy. LWGDTD was positioned in the middle of the draft tube deck.

Study Results

The study results are presented by project in the following sections of this report.

McNary Dam. Water temperature as monitored at the alternative TDG monitor stations is depicted in Figure 12. The McNary forebay temperature ranged from 10 °C in early May up to 20-24 °C by July. Two stations, MCNDTD and MCNFBRZP1 had only a slight diel trend in the order of 0.1-0.2 °C as contrasted to the 2-4 °C spikes as noted for the other two alternative stations as well as for the forebay monitors shown in figure 1 and 2. Figure 13 depicts the thermal profile from surface to bottom for the McNary forebay. Surface warming is shown to extend intermittently down to between 5 and 10 meters deep in this area.

The McNary Dam forebay TDG time history plots for the alternative sampling station data as compared to the established forebay station data is presented in Figures 14 through 17. The TDG saturation ranged from 105 % up to 120% across all stations. The MCNDTD and MCNFBBRZP1 data, Figures 14 and 15, tracked along consistently with the lower TDG pressures for the forebay monitors, MCQO and MCQW. The routine fixed monitor data for both MCQO and MCQW are characterized by wide diel fluctuations in TDG, 5-6 percent saturation, whereas the draft tube instrument, MCNDTD and the upstream BRZ instrument showed much smaller daily fluctuation in the order of 1-2 percent saturation. Time histories for both MCNFBFMSP1 and MCNFBFMSP2, Figures 16 and 17 respectively, followed the FMS TDG closely and were similarly characterized by the wide diel fluctuations in pressure (2- 5 % saturation).

Ice Harbor Dam. Water temperature as monitored at the alternative TDG monitors stations is depicted in Figure 18. The Ice Harbor forebay temperature varied from 10 °C in late April up to 17 °C in late June. Diel cycles were limited to 1 °C for the alternative TDG monitors versus the 2-3 °C apparent for the IHR forebay fixed monitor. Figure 19 depicts the thermal profile from surface to bottom for the Ice Harbor Dam forebay. Surface warming is shown to extend intermittently down to between 3 and 5 meters deep in this area. The warming the 5 meter depth was generally less than 1 °C.

The Ice Harbor Dam forebay TDG time history plots for the alternative sampling station data as compared to the established forebay station IHR is presented in Figures 20 through 23. The TDG saturation ranged from 110 % up to 124% across all stations. The IHRDTD TDG data was characterized by frequent decreases in saturation as seen in figure 20. The IHRFBFMS, IHRFBNL, and IHRFBBRZ data shown in Figures 21, 22, and 23 respectively tracked along consistently with the lower TDG pressures for the forebay monitor IHR and demonstrated only minor diel fluctuations in saturation. The IHR routine fixed monitor data are characterized by thermally induced pressure diel variation resulting in wide diel fluctuations in TDG, 5-6 percent saturation.

Lower Monumental Dam. The alternative TDG monitor stations water temperature data time histories are depicted in Figure 24. The Lower Monumental forebay temperature varied from 10 °C in late April up to 18 °C by late June. Diel cycle were limited to 0.5 °C for stations LMNDTD, LMNFBBRZ, and LMNFBNL versus a 2 °C swing noted for both the fixed monitor, LMN, and the LMNFBFMS station. Figure 25 depicts the thermal profile from surface to bottom for the Lower Monumental Dam forebay. Surface warming is shown to extend intermittently down to between 3 and 5 meters deep in this area. The warming the 5 meter depth was generally less than 1 °C.

The Lower Monumental forebay TDG time history plots for the alternative sampling data as compared to the forebay fixed monitor LMN is presented in Figures 26 through 29. The TDG saturation ranged from approximately 105% up to a high of 129 % during the spill season across all stations. The diel variations noted for LMN most likely due to the Little Goose project operation day/night daily spill cycles. The daily cycles due to upstream operation was also well represented by the alternative monitors. However there were four temperature spikes with associated TDG spikes of 2% saturation present on June 4th through 7th. These thermal spikes were minimal for all of the alternative monitors. The alternative monitor TDG data was consistent with the lower baseline TDG pressures for the LMN fixed monitor data on days where thermal spikes were apparent.

Little Goose Dam. The Little Goose forebay water temperature time histories are depicted in Figure 30. These waters varied from 10 °C in late April up to near 18 °C by late June. Diel temperature cycles were limited to < 1 °C for stations LGSDTD, LGSFBFMS, LGSFBBRZ, and LGSFBNL versus the 2-3 °C swings noted for the forebay fixed monitor, LGS. Figure 31 depicts the thermal profile from surface to bottom for the Little Goose Dam forebay. As at Ice Harbor and Lower Monumental dam the

surface warming is shown to extend intermittently down to between 3 and 5 meters deep in this area. The warming the 5 meter depth was generally less than 1 °C.

The Little Goose forebay TDG time history plots for the alternative sampling station data as compared to the forebay fixed monitor, LGS, is presented in Figure 32 through 35. The TDG saturation ranged from approximately 100 % up to a high of 127 % during the spill season across all stations. Like as reported for Lower Monumental Dam there were a limited number of thermal spikes resulting in noticeable TDG spikes, 3-4 %, at the LGS fixed monitor during early June. Both LGSFBFMS and LGSFBBRZ TDG data tracked well with the LGS station differing only on the days with significant thermal spikes occurring during early June. The LGSFBNL alternative monitor TDG data was consistent with the lower baseline TDG pressures for LGS throughout the sample period and showed minimal daily cycling. Station LGSDTD was characterized by frequent increases of 3-5% TDG saturation likely due to noticeable spill jet entrainment for this project.

Lower Granite Dam. The Lower Granite forebay water temperature time histories are depicted in Figure 36. These waters varied from 9 °C in late April up to near 18 °C by late June. Diel temperature cycles were limited to < 0.5 °C for stations LWGDTD, LWGFBNL, and LGSFBBRZP2 versus the 2-3 °C swings noted for the forebay fixed monitor, LWG. The forebay thermal profile time history for Lower Granite Dam is shown in Figure 37. Of the projects included in the study Lower Granite pool warmed the most from top to bottom and by June the vertical temperature gradients remained with continued warming from day to day as the season progressed. The warming eventually extended down to 15 m.

The Lower Granite Dam forebay TDG time history plots for the alternative sampling station TDG data as compared to the established forebay station LWG is presented in Figures 38 through 40. The TDG saturation ranged from approximately 100 up to 110% across all stations. The LWGDTD TDG data was characterized by frequent increases in saturation of 5-10 % as seen in figure 38. Similar to that at Little Goose these excursions are likely due to spill jets entrainment into the powerhouse releases as measured by the draft tube instrument. The LWGFBBRZ and LWGFBNL data shown in Figures 39 and 40 respectively tracked along consistently with the lower TDG pressures for the forebay monitor LWG and demonstrated only minor diel fluctuations in saturation. The LWG routine fixed monitor data are characterized by thermally induced pressure diel variation resulting in wide diel fluctuations in TDG, 3-5 percent saturation.

Study Analysis

A water quality compliance parameter was calculated based on the state water quality standard for TDG and the fish spill season waiver for each fixed monitor and alternative monitor site used in the study. The parameter is calculated as the average of the highest 12 hourly reading on each calendar day and then compared to the water quality waiver standard of 120 % saturation for tailwater monitors and 115 % saturation

for downstream forebay monitors. Those values greater than the waiver standard are then considered to be out of compliance. The calculated compliance parameter values are listed in Tables 1 – 5 by project. Comparisons can be made between the fixed monitor station and the alternative sites for each dam. However in some cases such as for IHRFBNL in Table 2 and LGSDTD in Table 3 there was insufficient data available for the same days as for the other stations to make the comparison. The highest number and percent total of exceedences was calculated for Ice Harbor Dam (61%) and Lower Monumental Dam (63%) forebay fixed monitors. Little Goose and McNary dams followed with 36% and 31% respectively. Lower Granite stations reported no exceedances for the sampling period.

It was assumed that those stations characterized by the more prominent daily spikes in TDG as is the case for the routine fixed monitors would possibly results in the highest number of exceedances. This apparently was the case for Ice Harbor Dam and McNary Dam stations. The alternative TDG stations for both Ice Harbor and McNary dams showed some decreases in exceedance numbers and percentages. IHRFBBRZ had 26 exceedances for the same days that IHR reported a total of 33 daily exceedances. The McNary station MCNFBBRZ1 report 12 of 55 days exceeding versus the 17 reported for both MCQO and MCQW. The Lower Monumental and Little Goose data showed little change in the number of exceedances for the alternative stations versus the fixed monitors.

Statistical comparisons were completed of the calculated compliance parameter for each alternative monitor location versus the routine fixed monitor in each case. These data are presented in Table 6 the paired sample statistics and Table 7 which list the paired sample test statistics. The two forebay fixed monitors at McNary showed no statistical difference (alpha = 0.05) in TDG which implies that during the 2003 season and for the 54 days of data used there were minimal differences from the north side (MCQW) to the south side (MCQO) of the river in the McNary forebay. These same two stations showed little difference with the alternate monitors located 5 m deeper and adjacent to them. The McNary monitors both averaged about 1 % saturation higher than the BRZ instrument and about 1.5 % higher than the draft tube deck instrument. This bias is likely due to the elevated pressures related to the thermal spikes at the fixed monitors.

The Ice Harbor alternative forebay stations all were significantly lower (approximately 0.3 – 0.5 % saturation) than the fixed monitor (IHR) for the same period. Similar differences are depicted in Table 7 for both Lower Monumental and Little Goose dams. The one exception was for LMNFBNL which resulted in a little higher average (0.43 % saturation) than LMN.

The Lower Granite Dam forebay stations showed lower average TDG for both LWGFBBRZ and LWGFBNL by 0.98 and 0.73 % saturation respectively than the LWG station. In the case of Lower Granite the fixed monitor, LWG, is located on the upstream tip of the navigation lock guide wall so LWGFBNL is located at the same location but at 10 m rather that 5 m deep.

Conclusions

Thermally induced pressure spikes in TDG were observed at the forebay fixed monitors for all of the Lower Snake River projects and McNary Dam during the test period some exceeding 5 % saturation on a daily basis. These phenomena are likely due to near field hydrodynamics coupled with vertical thermal gradients in the water columns. The more significant occurrences were identified for McNary and Lower Granite dams. These sites also resulted is a relatively high number of exceedances of the water quality standard for TDG for the study period. The data suggests the fixed monitor instruments can often report TDG values that are not representative of the forebay waters and are biased by surface waters. Because of this bias the station may not meet the requirements or purpose for the water quality station as described in the introduction.

Those monitors that are located on or near the upstream face of the powerhouse can impacted by the down welling of the warm surface waters which result in the ambiguous and none representative spiking of the TDG. This down welling results from nearby turbine intake during project generation unit operation. The spiking occurs associated with the daily surface warming that typically occurs in the river. Note that this affects pressure but not concentration of gases. The monitors that fall into the area of potential impact are MCQO, IHR, LMN, and LGS. The alternate stations that were located at the same locations but deeper in the water column were often equally affected by down welling of the warmer surface waters. The one exception was at IHRFBFMS which showed improvements similar that for other stations away from the project face.

MCQW and LWG are both positioned upstream of the project face with no vertical walls to interfere or redirect surface flows. However, in each of these cases significant surface warming to depth occurs on a routine basis. This warming routinely extends to between 5 and 10 m at McNary and down to 15 m at Lower Granite forebay. This warming was sufficient to impact the monitor measures at these stations. In both cases the deeper (10 m) alternative stations, LWGFBNL and MCNFBFMSP2, gave more representative measures for the entire water column than the fixed monitors at the shallower depths.

The draft tube deck instruments produced mixed results in relation to the forebay fixed monitors. Both MCNDTD and LMNDTD produce rather smooth TDG time histories with little indication of thermal spikes or TDG increases associated with entrainment of spill waters. On the other hand however IHRDTD, LGSDTD, and LWGDTD all resulted in somewhat erratic data likely due to contamination from spill jet entrainment.

The instruments located adjacent to the fixed monitors and 10 m deep on the upstream face of the powerhouse also produced mixed results. Both MCNFBFMSP1 and MCNFBFMSP2 TDG data tracking well with the somewhat erratic MCQO and MCQW instrument data respectively. The other FMS alternate stations produced TDG data that

appeared representative with only intermittent pressure spikes related to temperature fluctuations.

Alternate TDG instruments positioned upstream of the dam face either suspended from buoys or hanging from floating wing walls were consistent in being the least effected by the thermal related pressure spikes and tracked well with the baseline data from the fixed monitor stations. These stations generally produced slightly lower average TDG % saturation during the test along with fewer days of exceedance for the state water quality standard (using the spill season waiver value).

The fixed monitors located at McNary Dam forebay MCQO and MCQW gave comparable data that was not determined to be significantly different for the study period This implies that one instrument would be adequate to address the needs for this project. The alternative stations at MCNFBBRZP1 and MCNFBFMSAP2 also gave comparable data.

Recommendations for Forebay Instrument Locations

The criteria to be used in decision making regarding the FMS stations are as follows.

- The recommendations will result in more representative data that should improve uses such as project management for TDG as well as water quality compliance evaluations
- These changes will improve the stations ability to achieve all design purposes mentioned in the introduction of this report.
- The recommendations regarding the forebay FMS station location should be consistent across all projects.
- The changes will result in minimal impact on operation and maintenance of each station if each new station can be accessed in a similar fashion as used for the existing stations.

In general the primary recommendations for improving the ability of the forebay fixed monitors to achieve there stated purposes is to eventually relocate each instrument to an area just upstream of the main project not affected by down welling of the often warmer surface waters and to a depth adequate to avoid thermal responses in the TDG pressure brought about by the general deepening of the warm surface layers. The simplest location to move to would be on the navigations lock guide wall similar to those stations used in the study. The water temperature for the selected depth strata should approximate the average temperature of the water column. Since the TDG instruments are capable of functioning properly at depths as deep as 20 m based on past experience manufacturer recommendations the proposed instrument should be at about 12-15 m. This would avoid most problems associated with the deepening surface layer as at Lower Granite or McNary dams.

Since the study conducted during 2003 was not exhaustive of every possible set of environmental conditions or variables that may be introduced by different water/weather years a transitions period is recommended prior to any permanent relocations of stations. During this transition period testing should continue similar to the 2003 effort but only at the locations and depths described above. The alternate TDG stations should be limited to the navigation lock guide wall locations tested in 2003 for the Snake River projects and at McNary continue testing the upstream BRZ site and add a guide wall station further towards the upstream tip of the wall. The transition period would extend through 2004 and be followed with a reevaluation regarding permanent relocation of the forebay FMS stations.

TDG FOREBAY FIXED MONITORING STATION REVIEW AND EVALUATION FOR LOWER SNAKE RIVER PROJECTS AND MCNARY DAM

Draft Report Figures

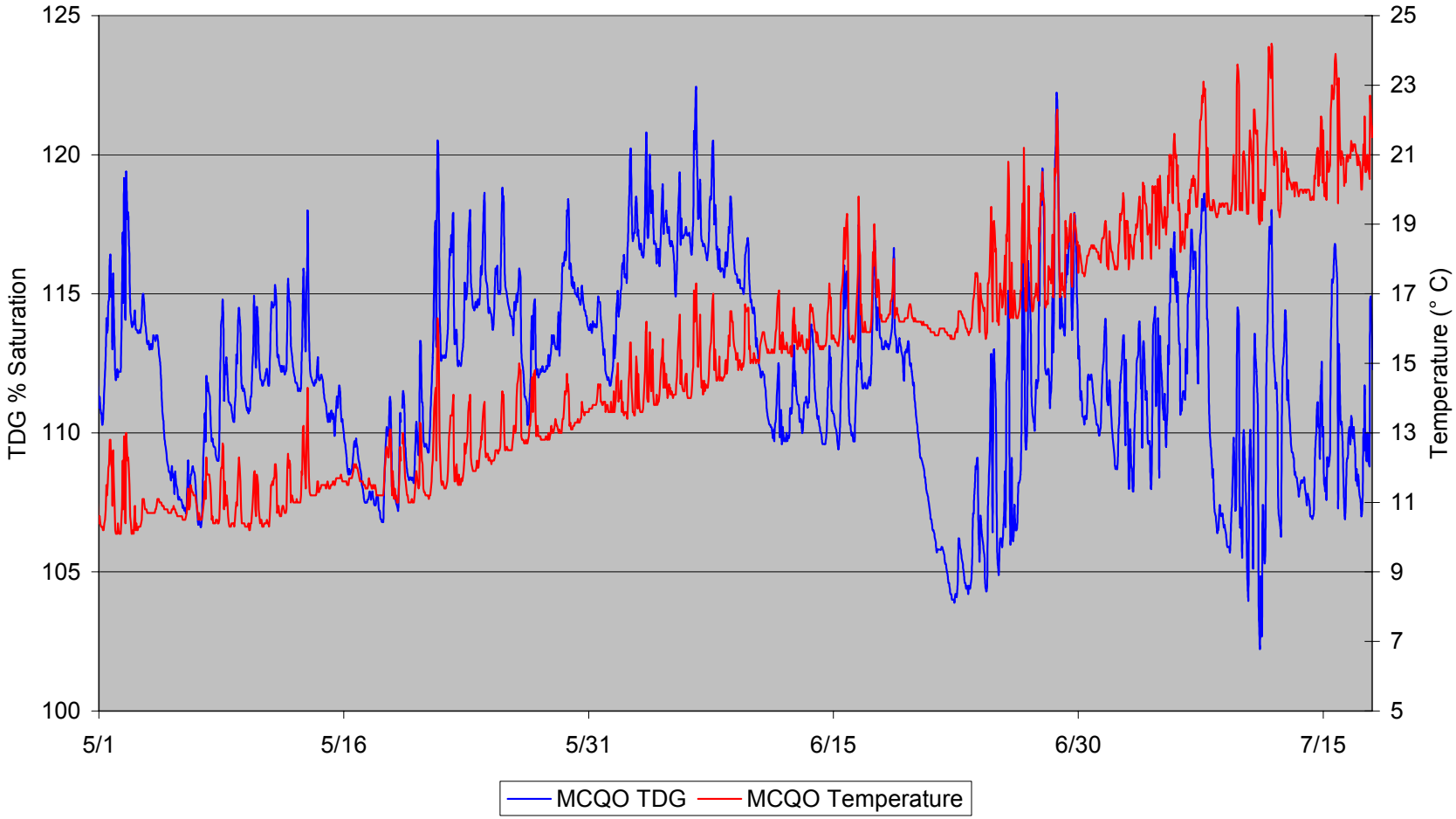

Figure 1. McNary Dam MCQO TDG and Water Temperature, 2003.

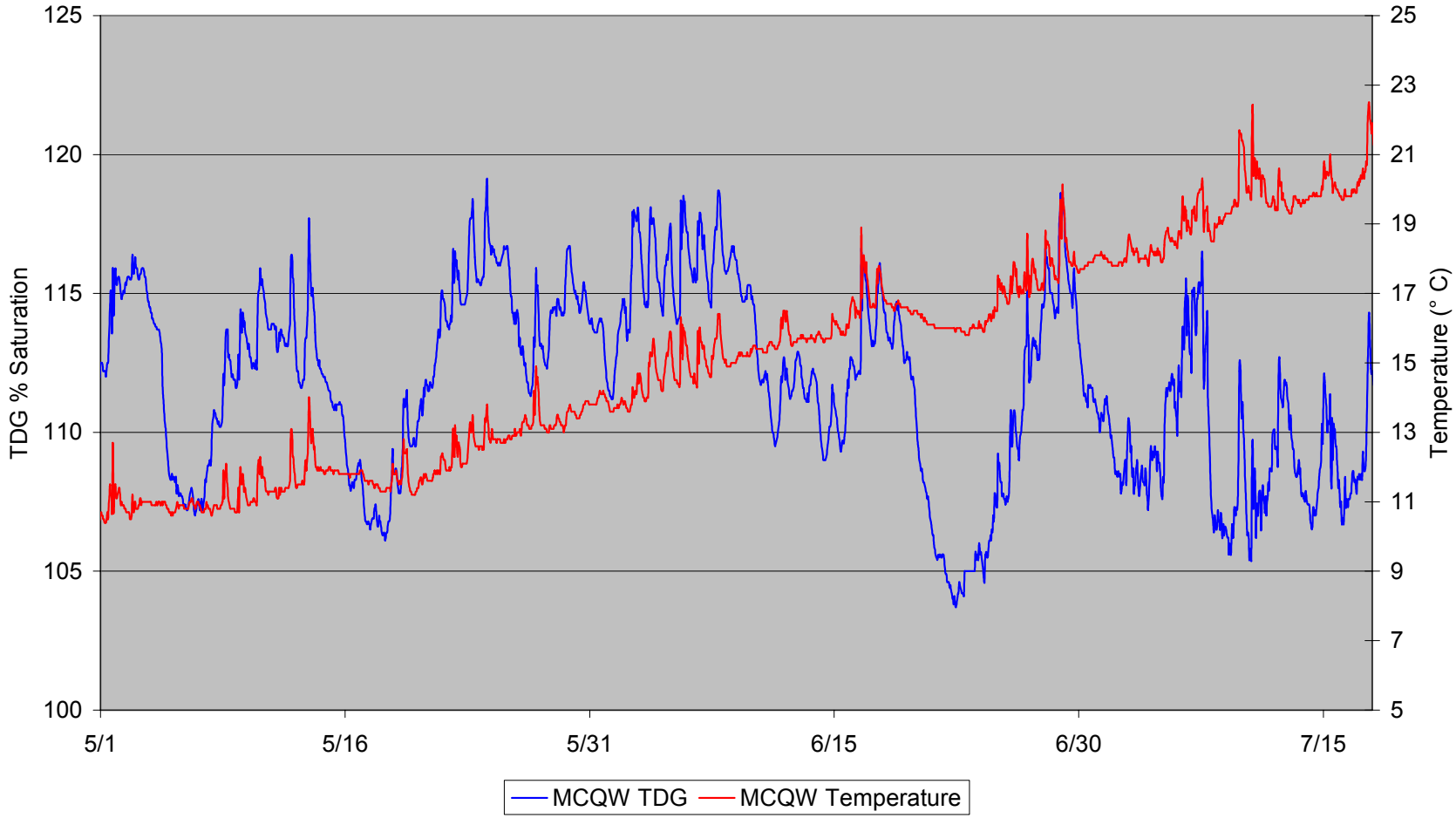

Figure 2. McNary Dam MCQW TDG and Water Temperature, 2003.

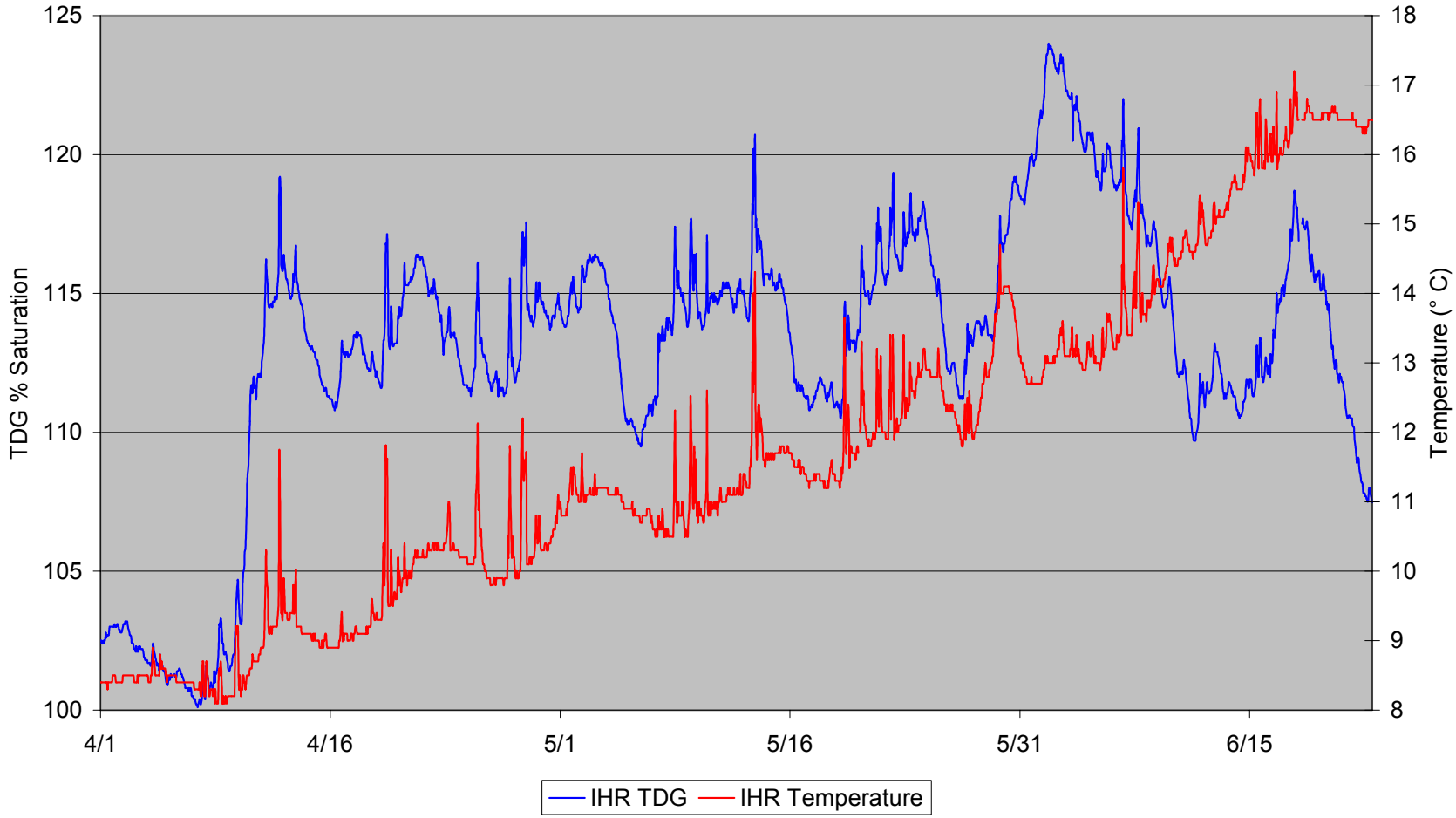

Figure 3. Ice Harbor Dam Forebay TDG and Water Temperature, 2003.

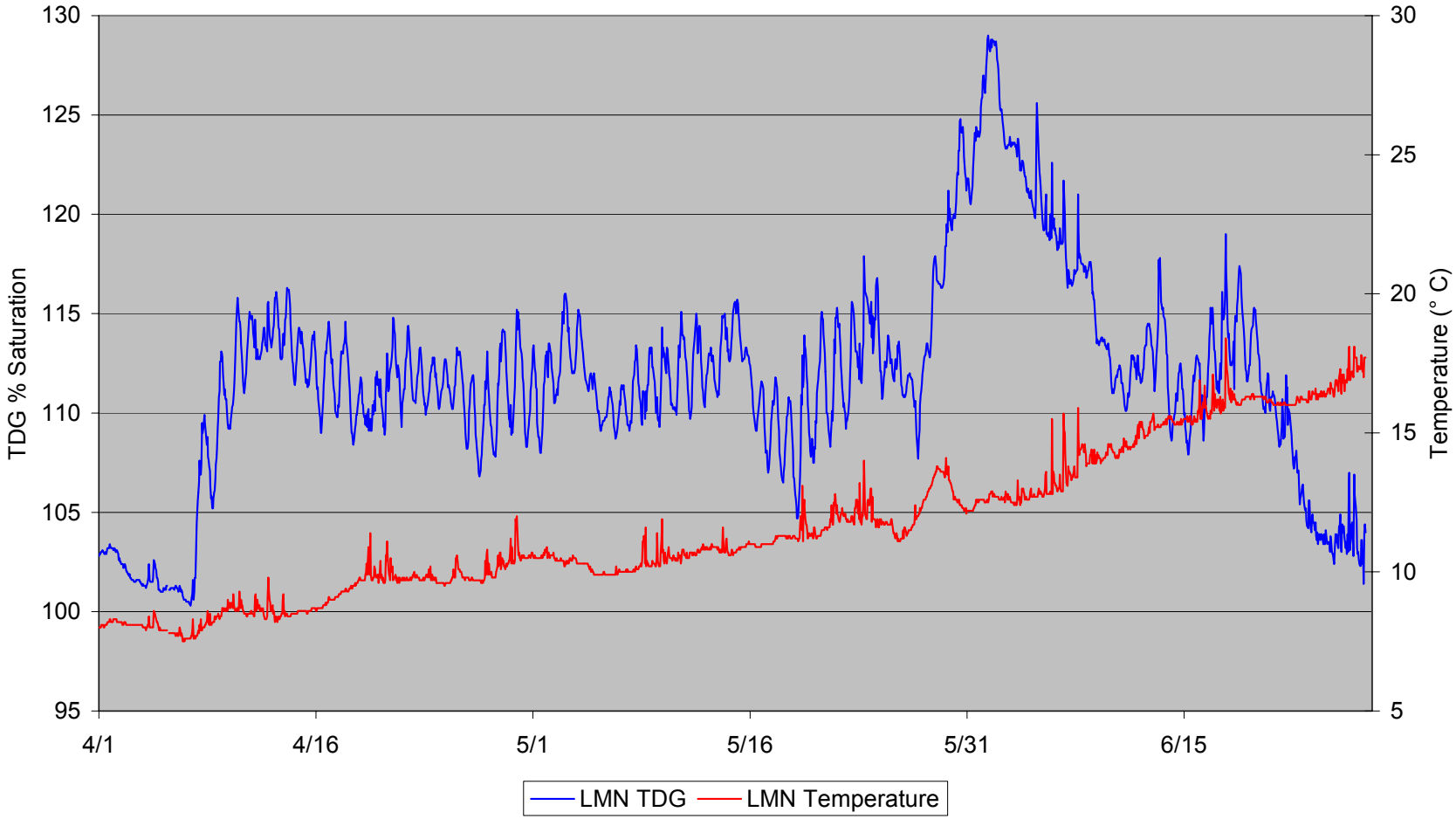

Figure 4. Lower Monumental Dam Forebay TDG and Water Temperature, 2003.

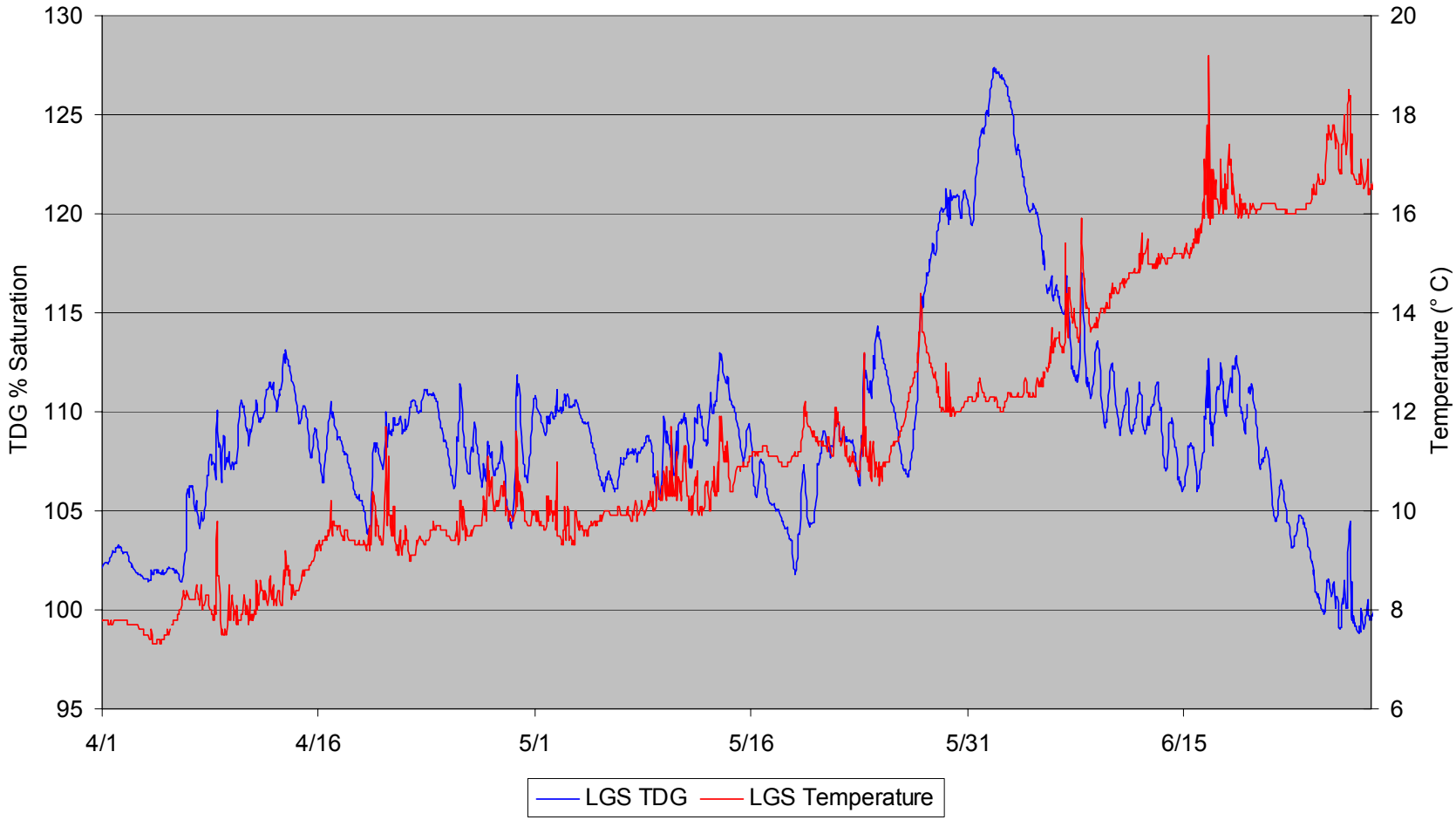

Figure 5 Little Goose Dam Forebay TDG and Water Temperature, 2003.

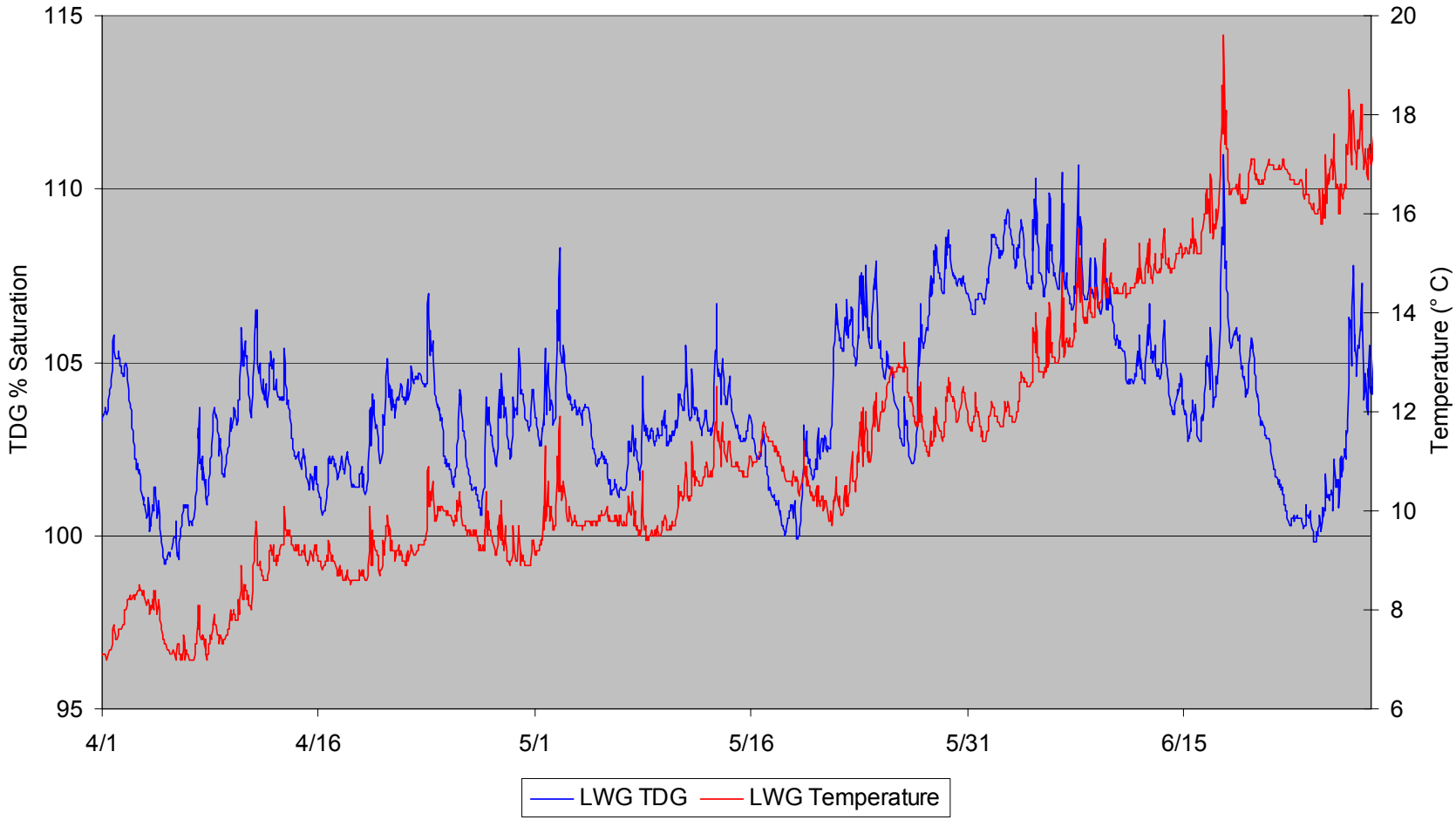

Figure 6. Lower Granite Dam Forebay TDG and Water Temperature, 2003.

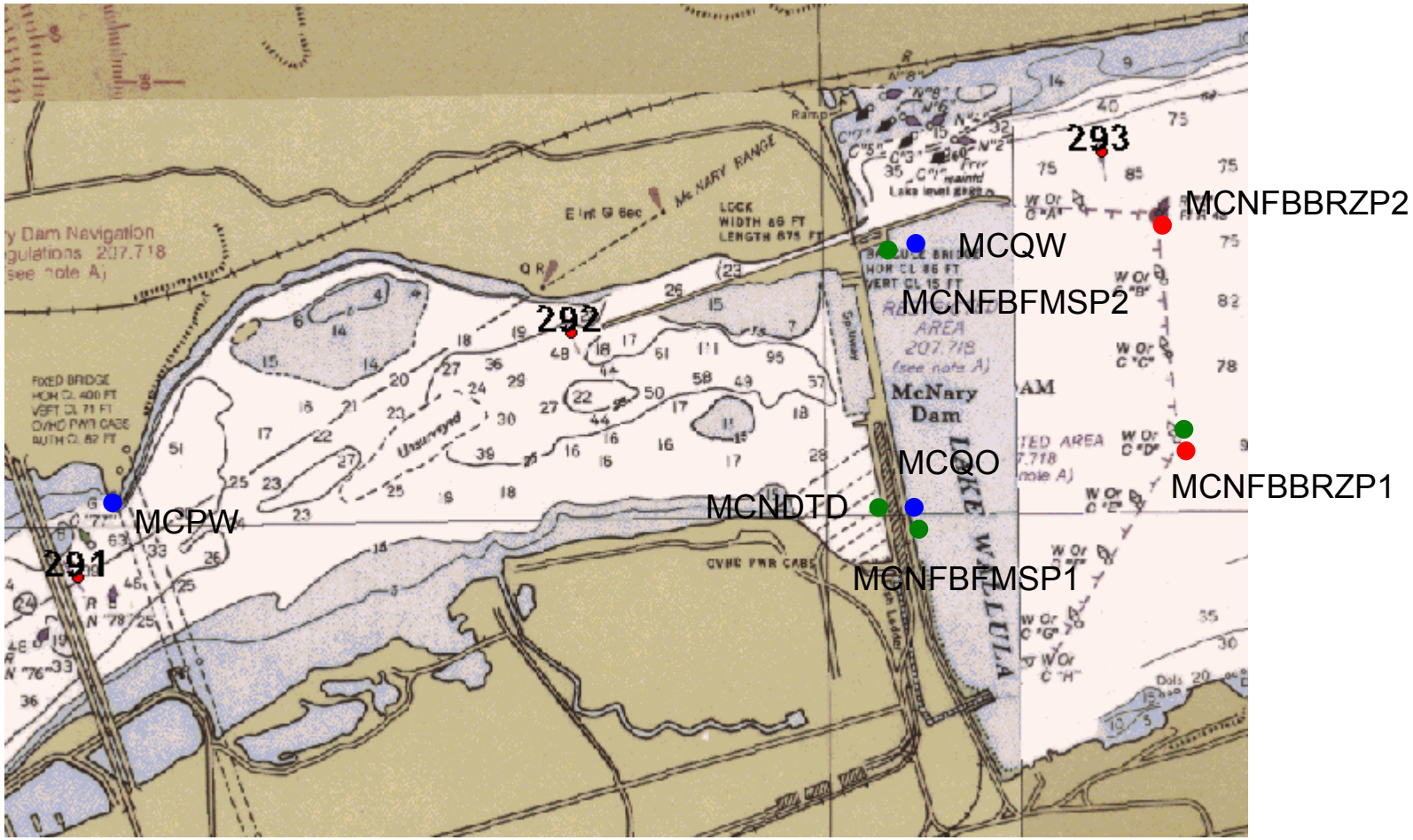

Figure 7. McNary Dam TDG FMS and RPA 132 alternative TDG stations.

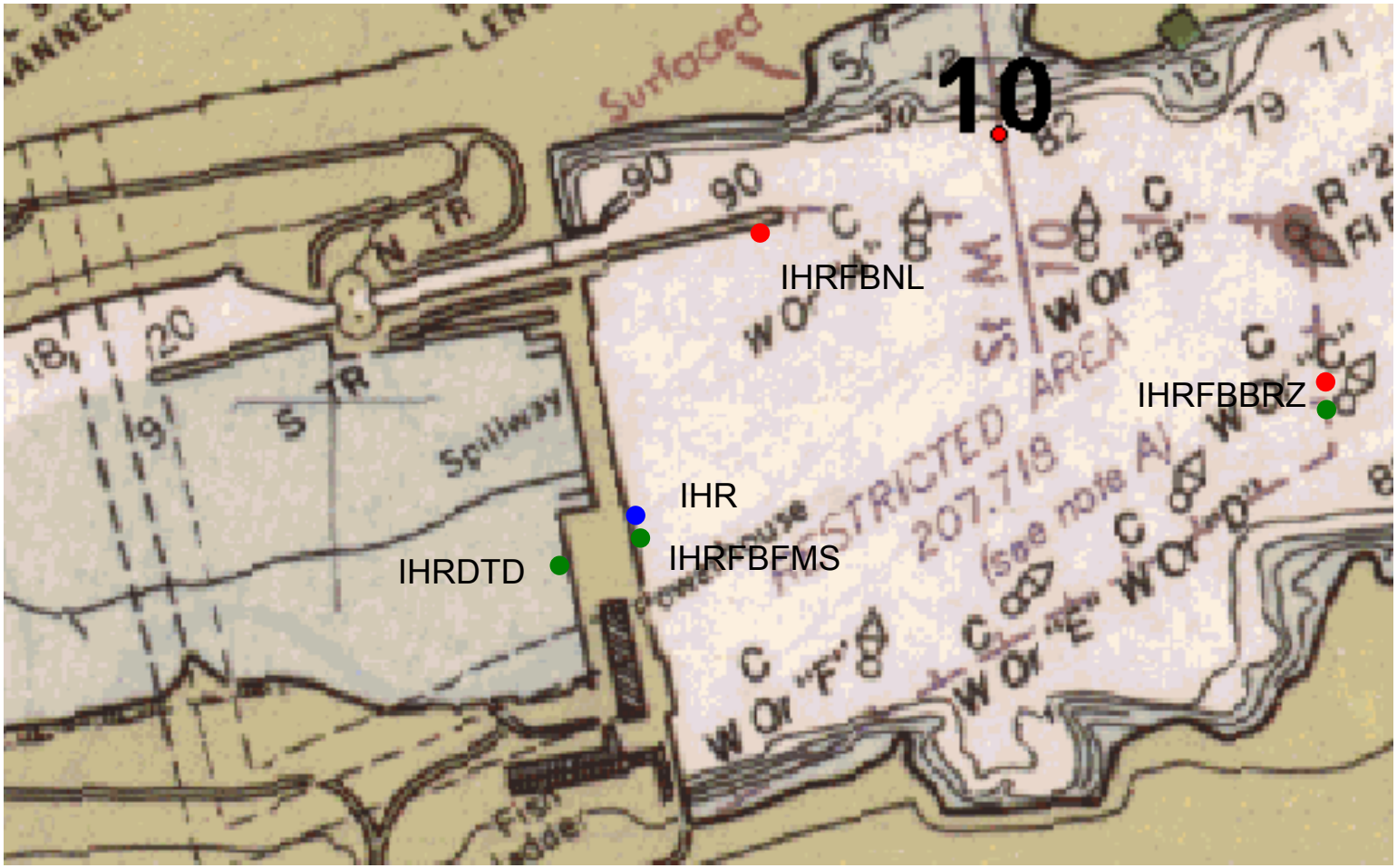

Figure 8. Ice Harbor Dam TDG FMS and RPA 132 alternative TDG stations.

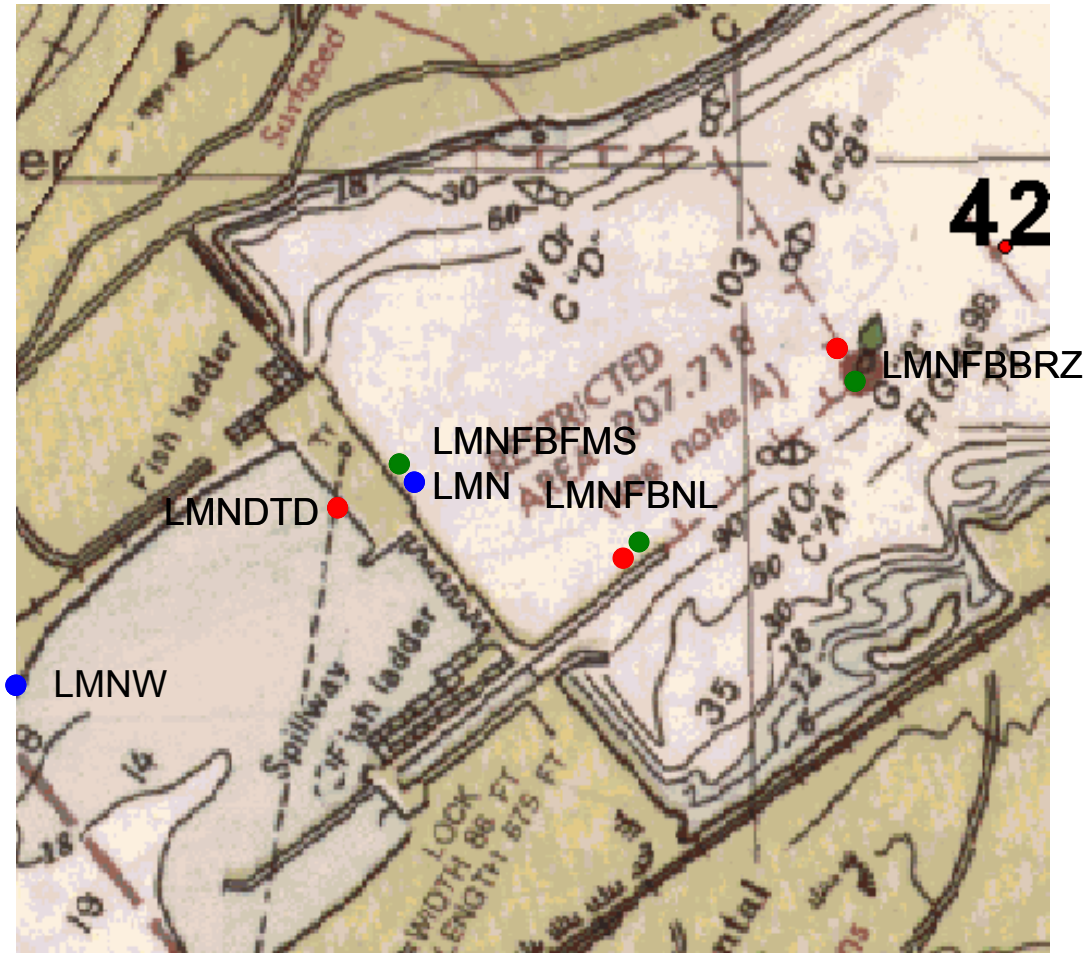

Figure 9. Lower Monumental Dam TDG FMS and RPA 132 alternative TDG stations.

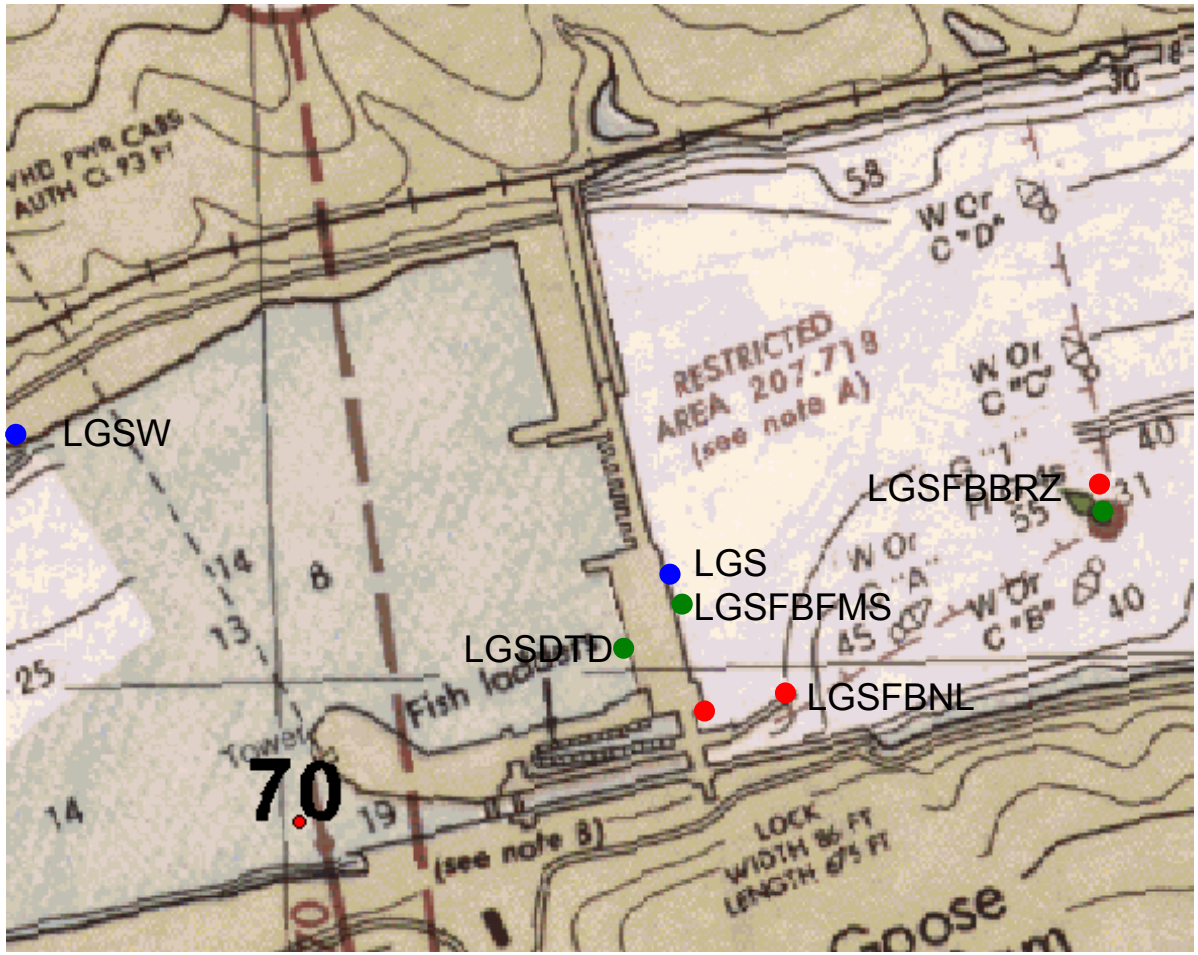

Figure 10. Little Goose Dam TDG FMS and RPA 132 alternative TDG stations.

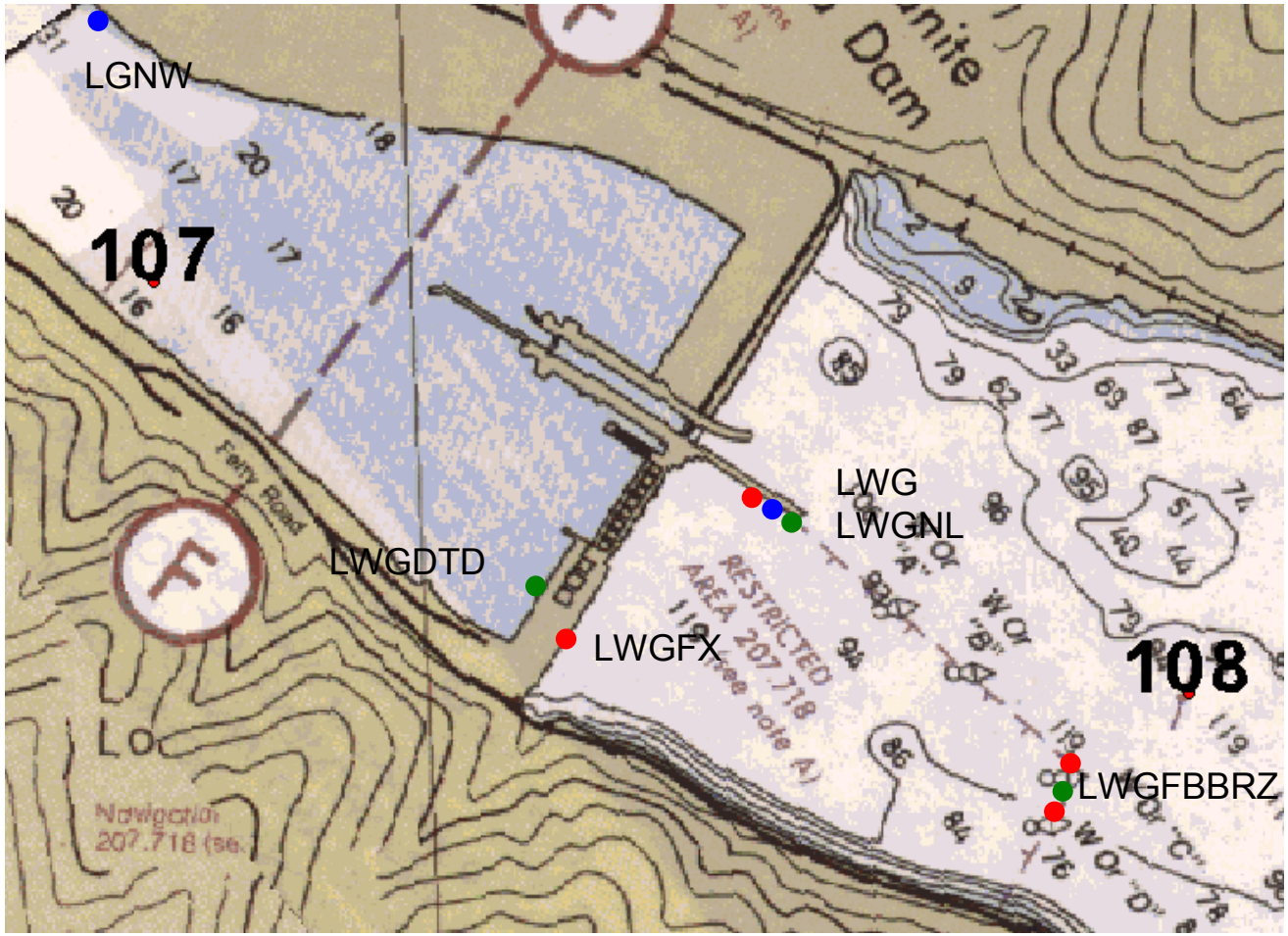

Figure 11. Lower Granite Dam TDG FMS and RPA 132 alternative TDG stations.

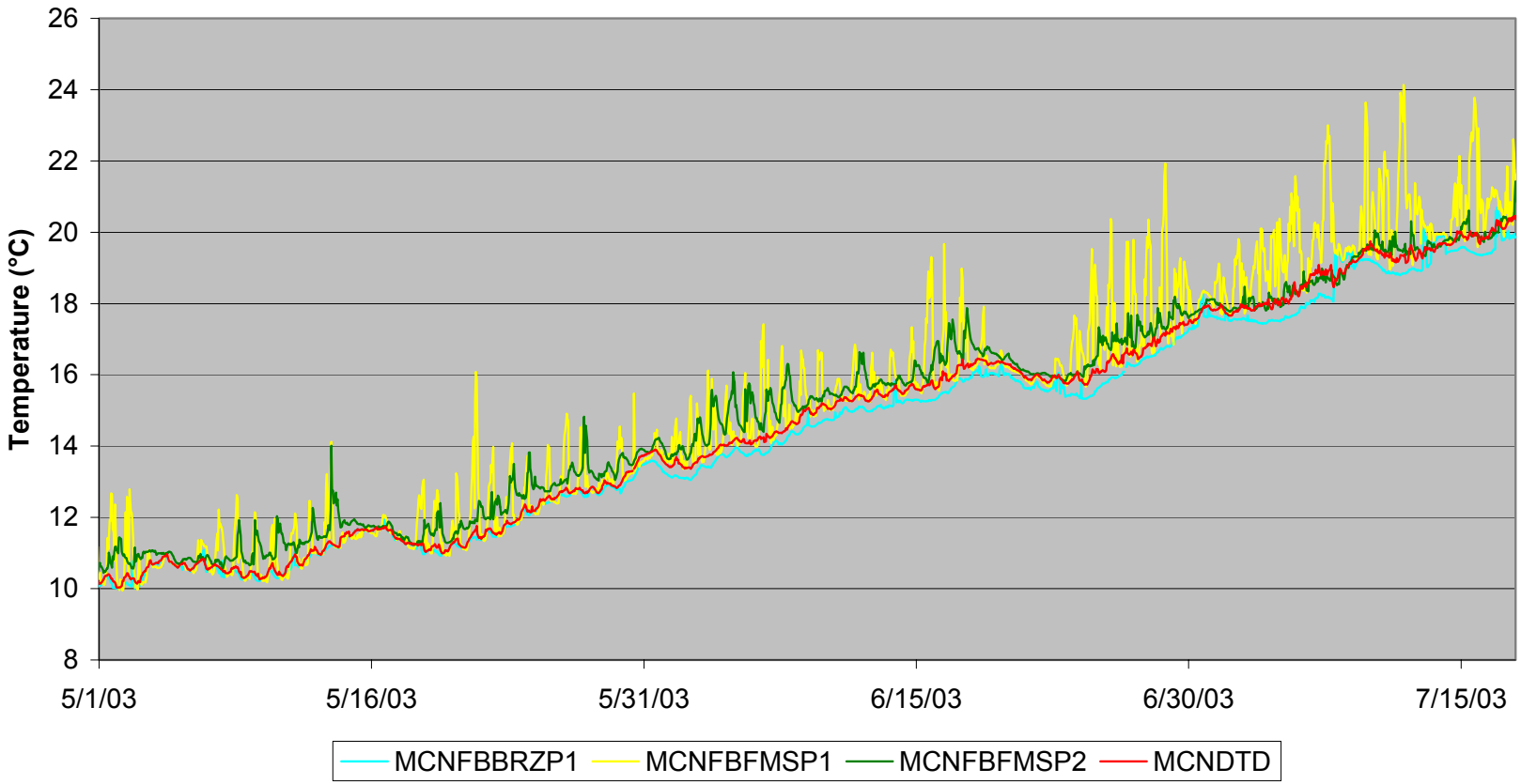

Figure 12. McNary Dam Alternate Monitor Station Temperature.

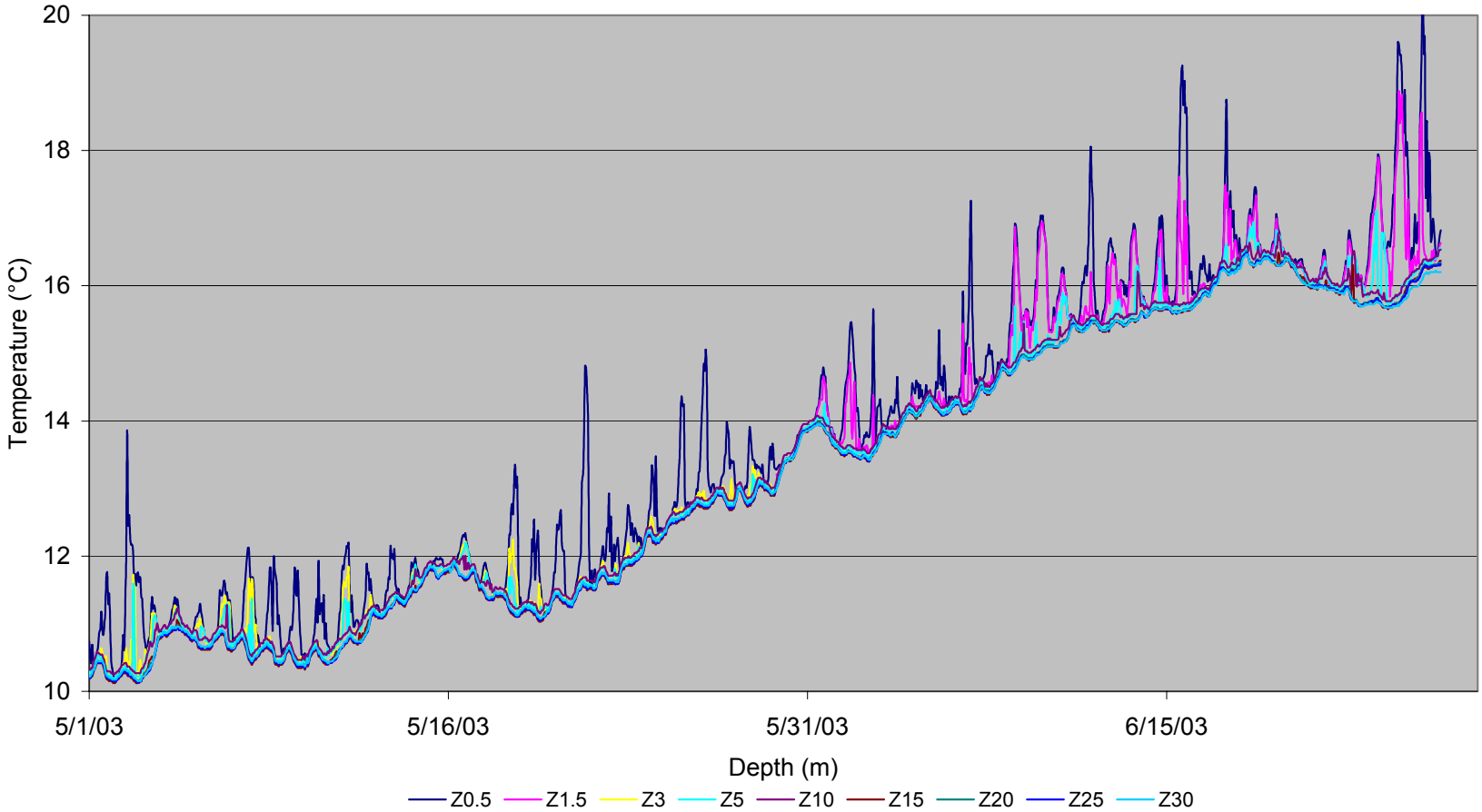

Figure 13. McNary Dam Forebay Thermal Profile.

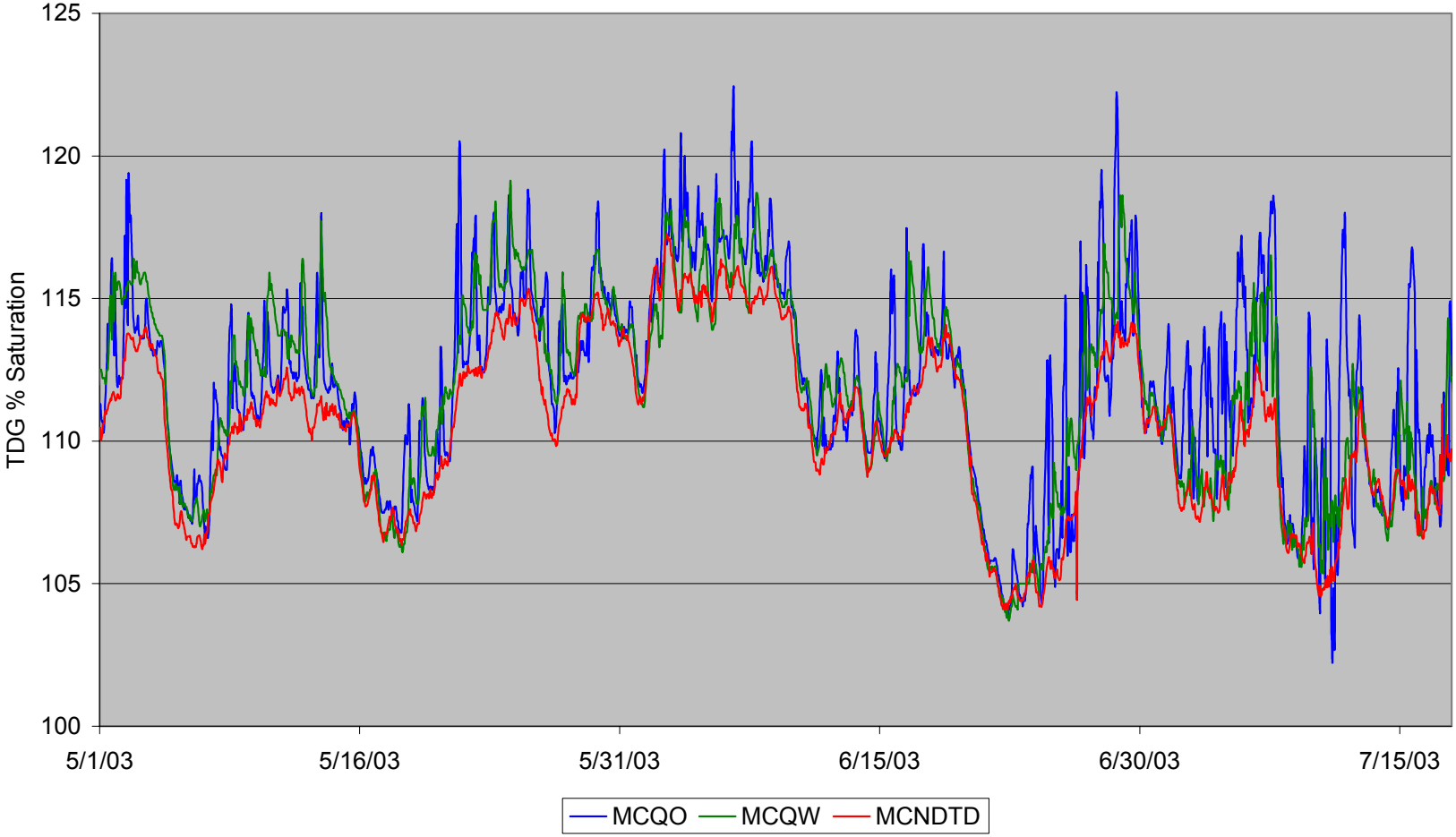

Figure 14. McNary Dam TDG Saturation MCQO, MCQW, and MCNDTD.

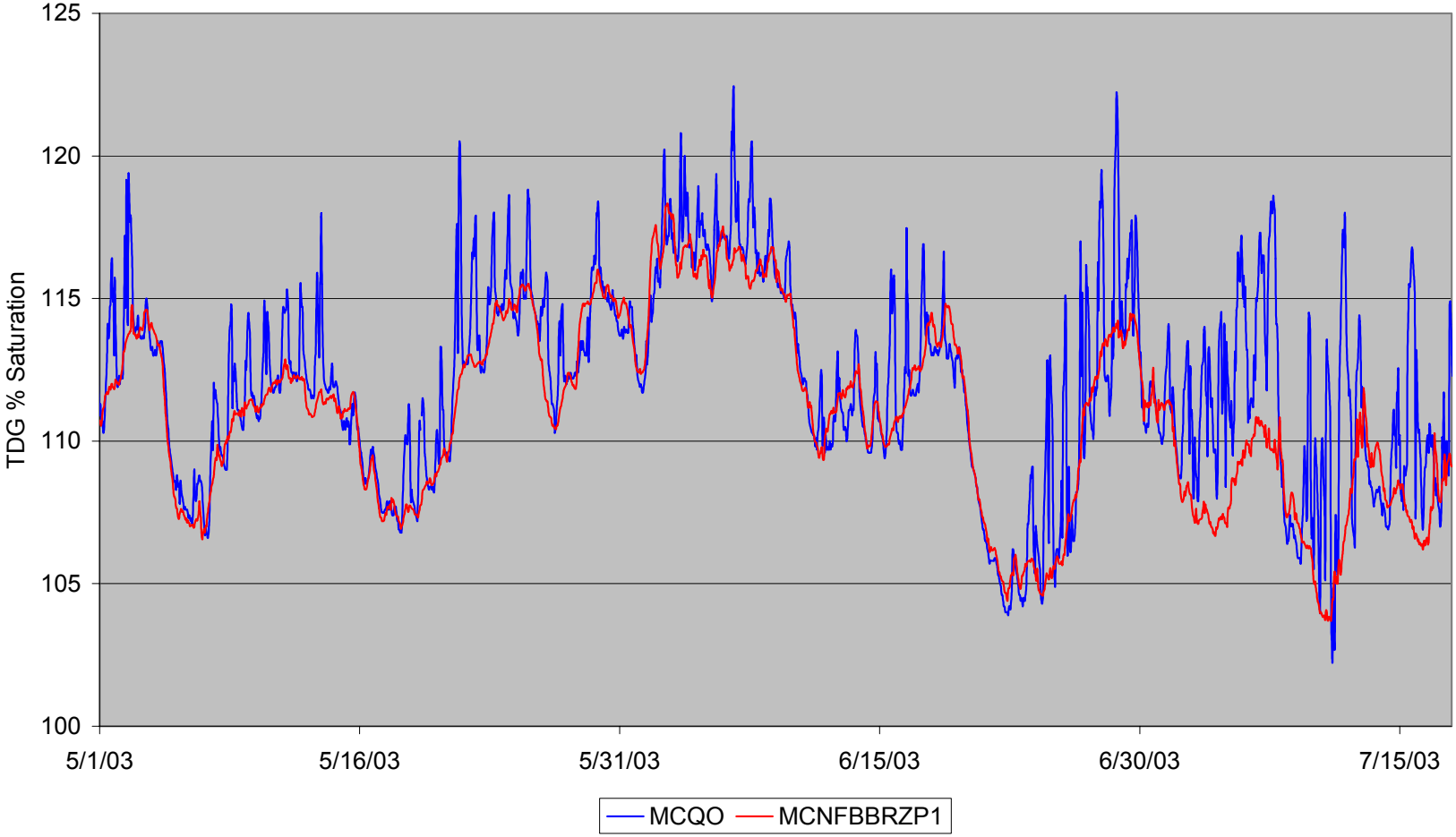

Figure 15. McNary Dam TDG Saturation MCQO and MCNFBBRZP1.

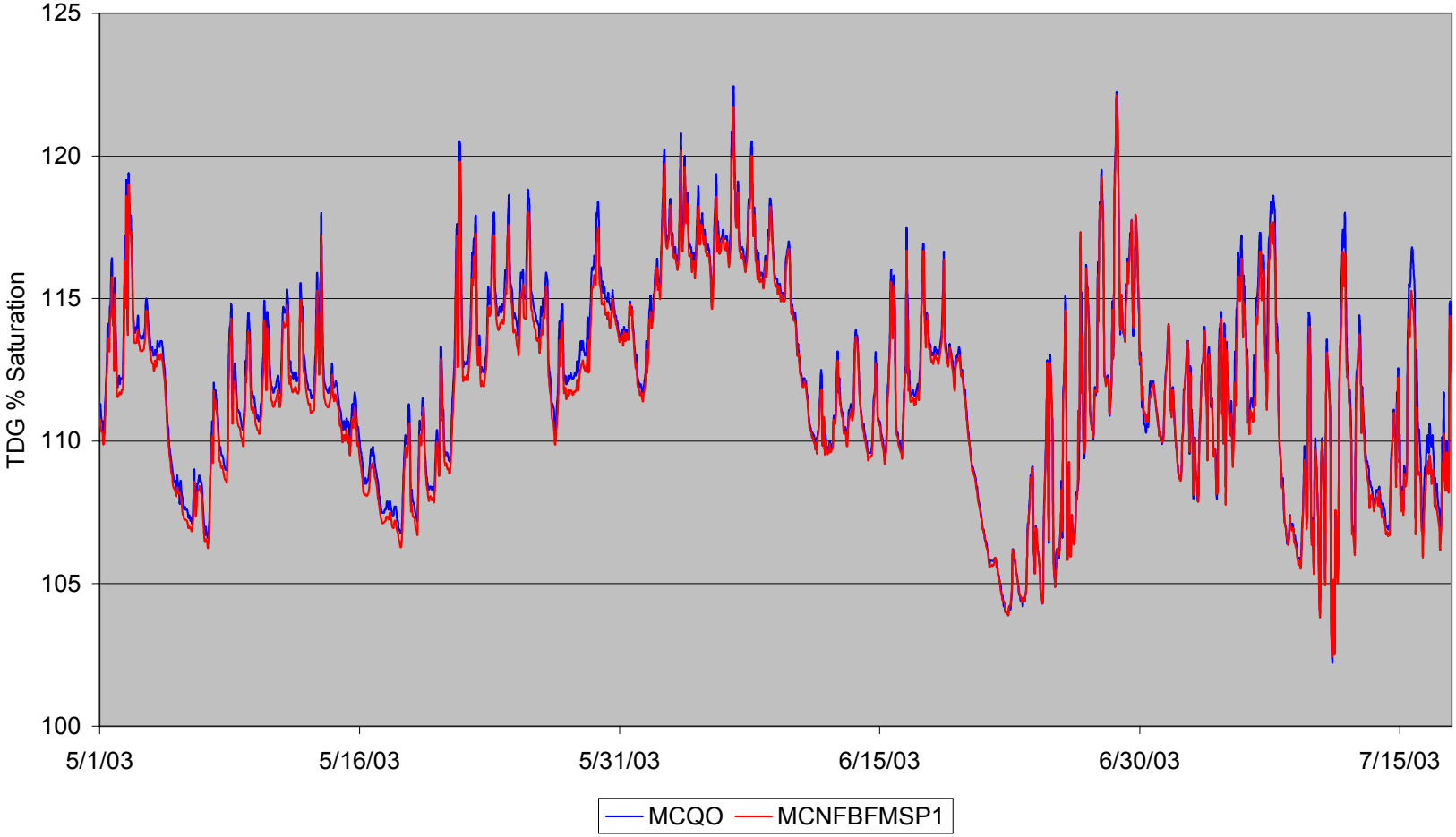

Figure 16. McNary Dam TDG Saturation MCQO and MCNFBFMSP1.

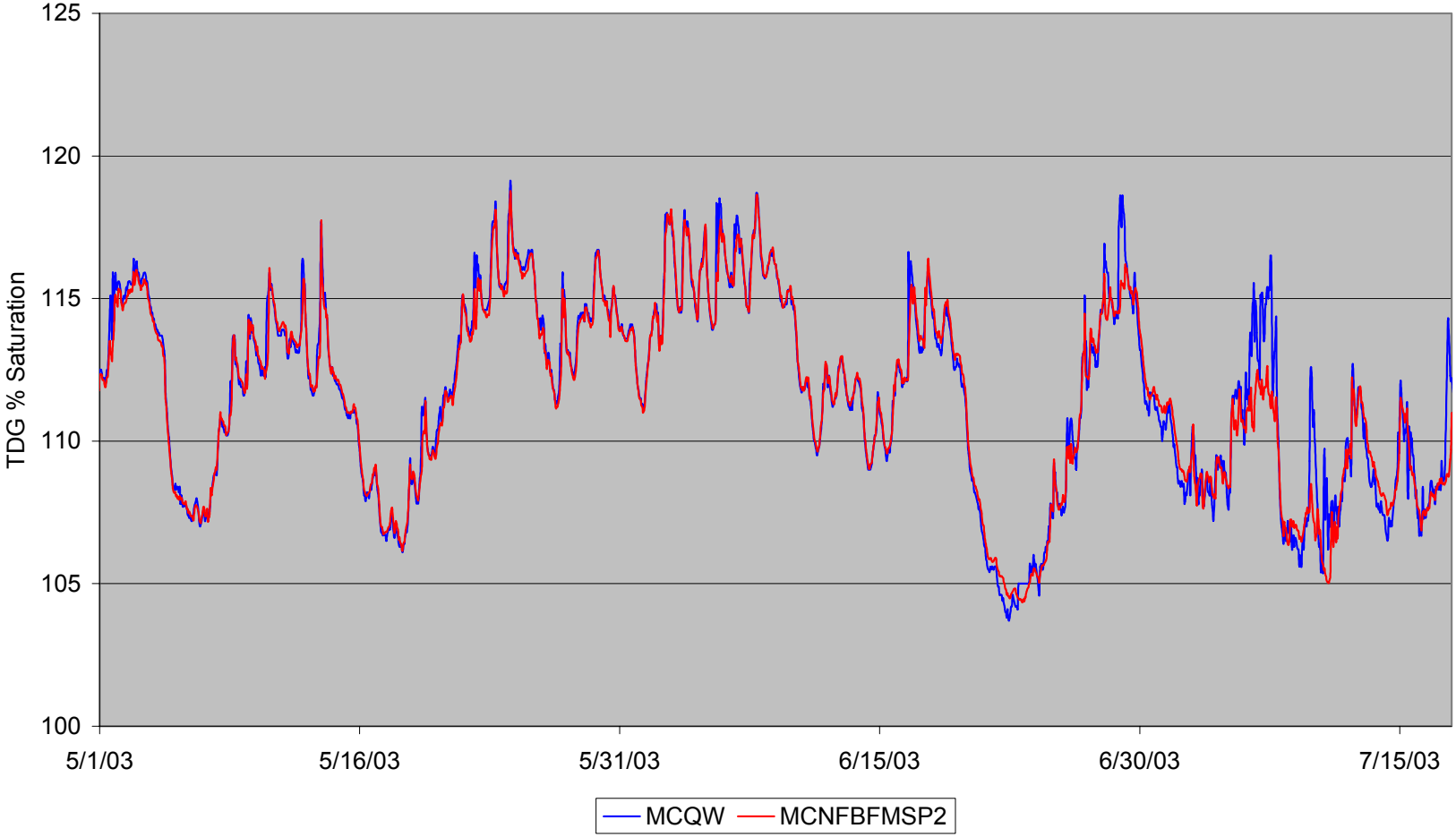

Figure 17. McNary Dam TDG Saturation MCQW and MCNFBFMSP2.

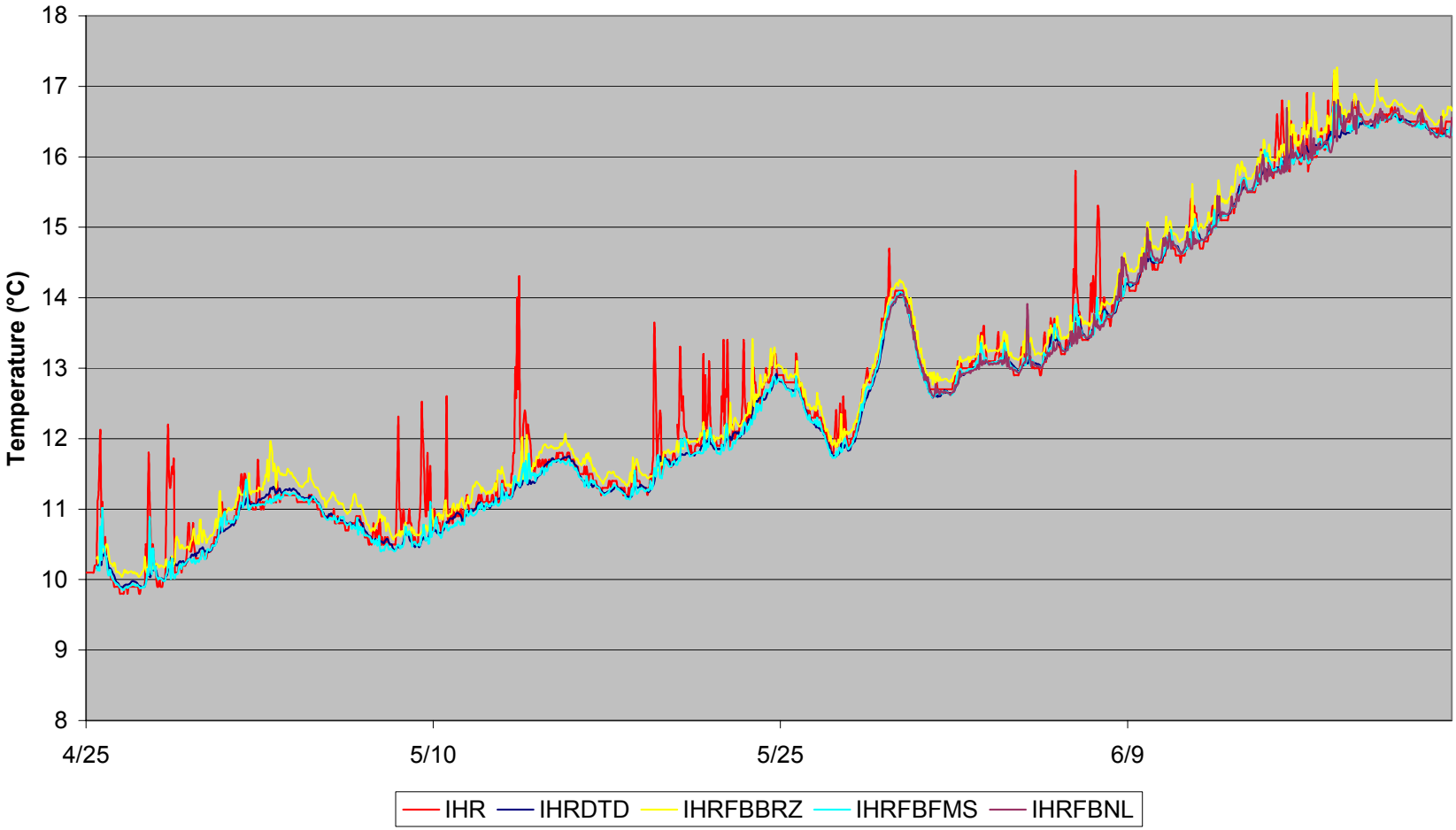

Figure 18. Ice Harbor Dam alternate TDG monitor station temperature.

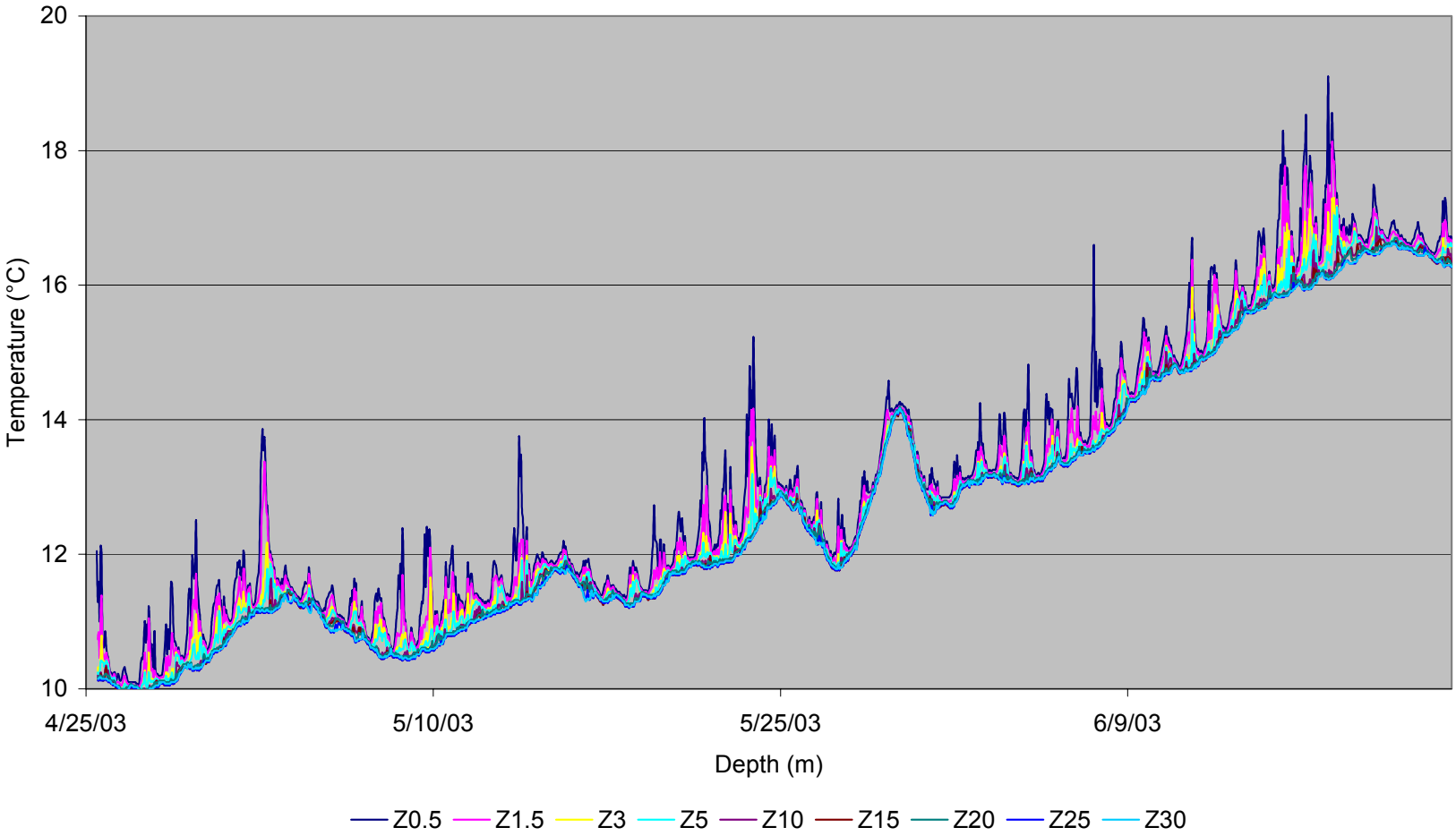

Figure 19. Ice Harbor Dam Forebay Thermal Profile.

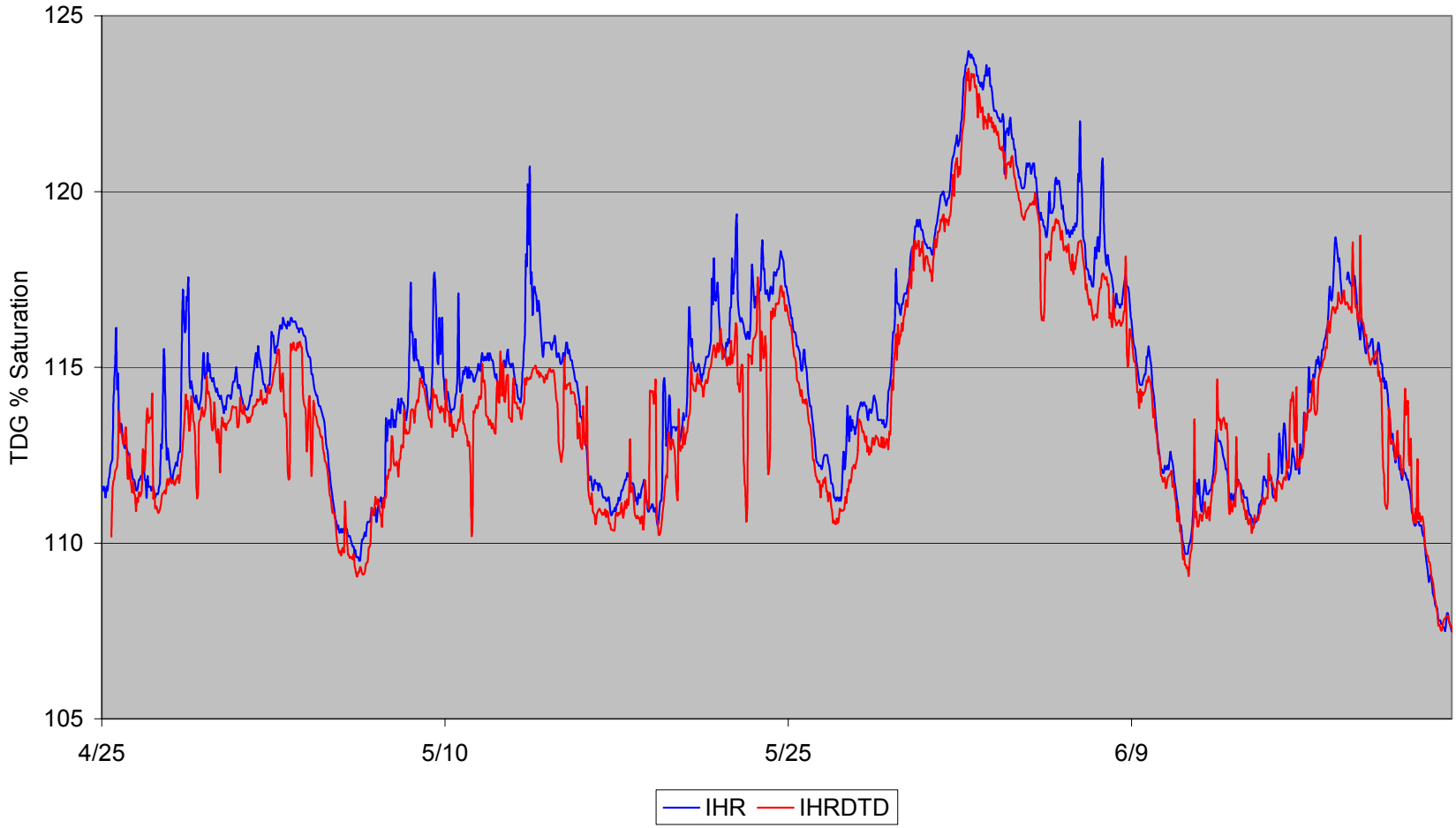

Figure 20. Ice Harbor Dam TDG Saturation IHR and IHRDTD.

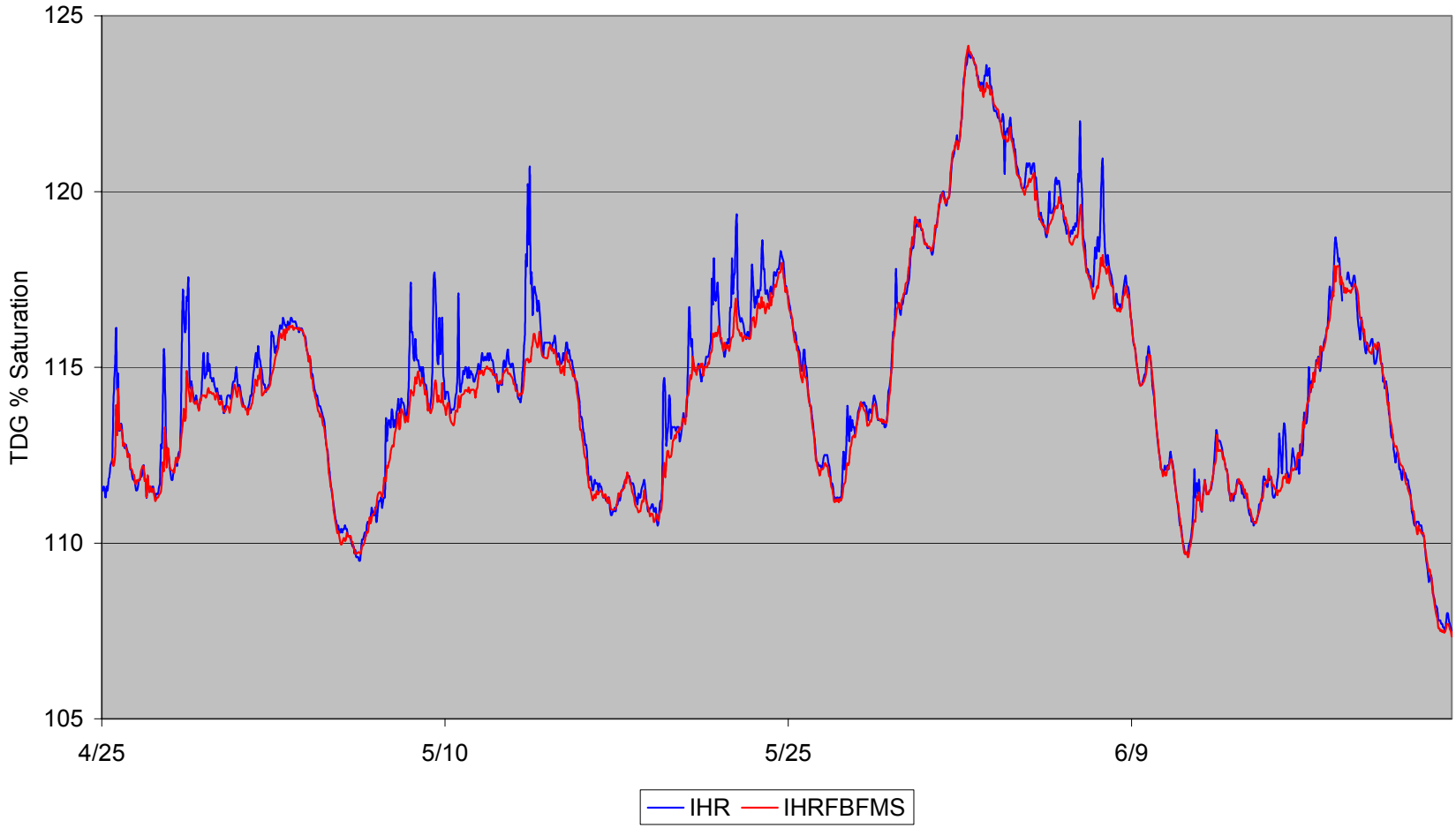

Figure 21. Ice Harbor Dam TDG Saturation IHR and IHRFBFMS.

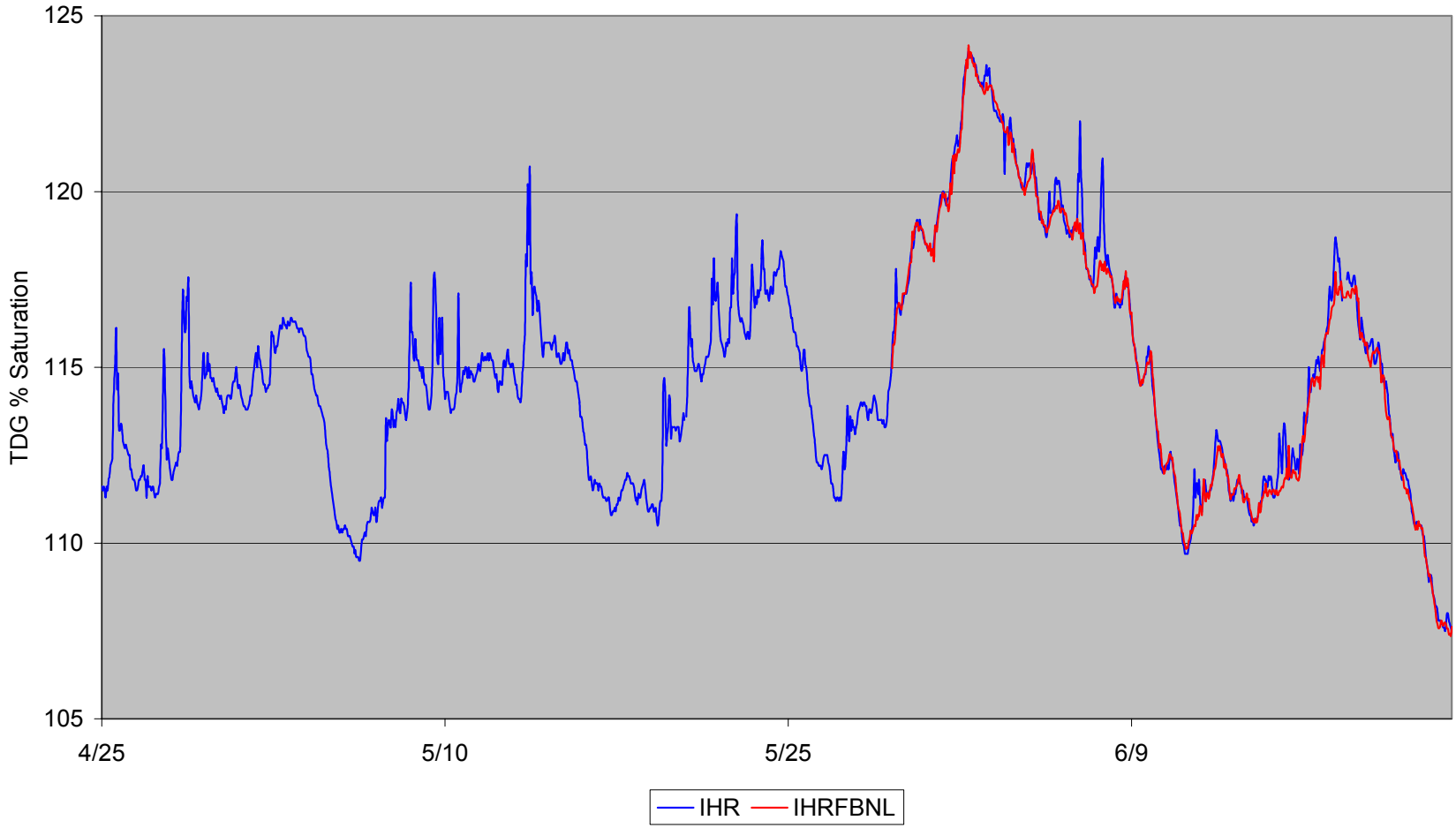

Figure 22. Ice Harbor Dam TDG Saturation IHR and IHRFBNL.

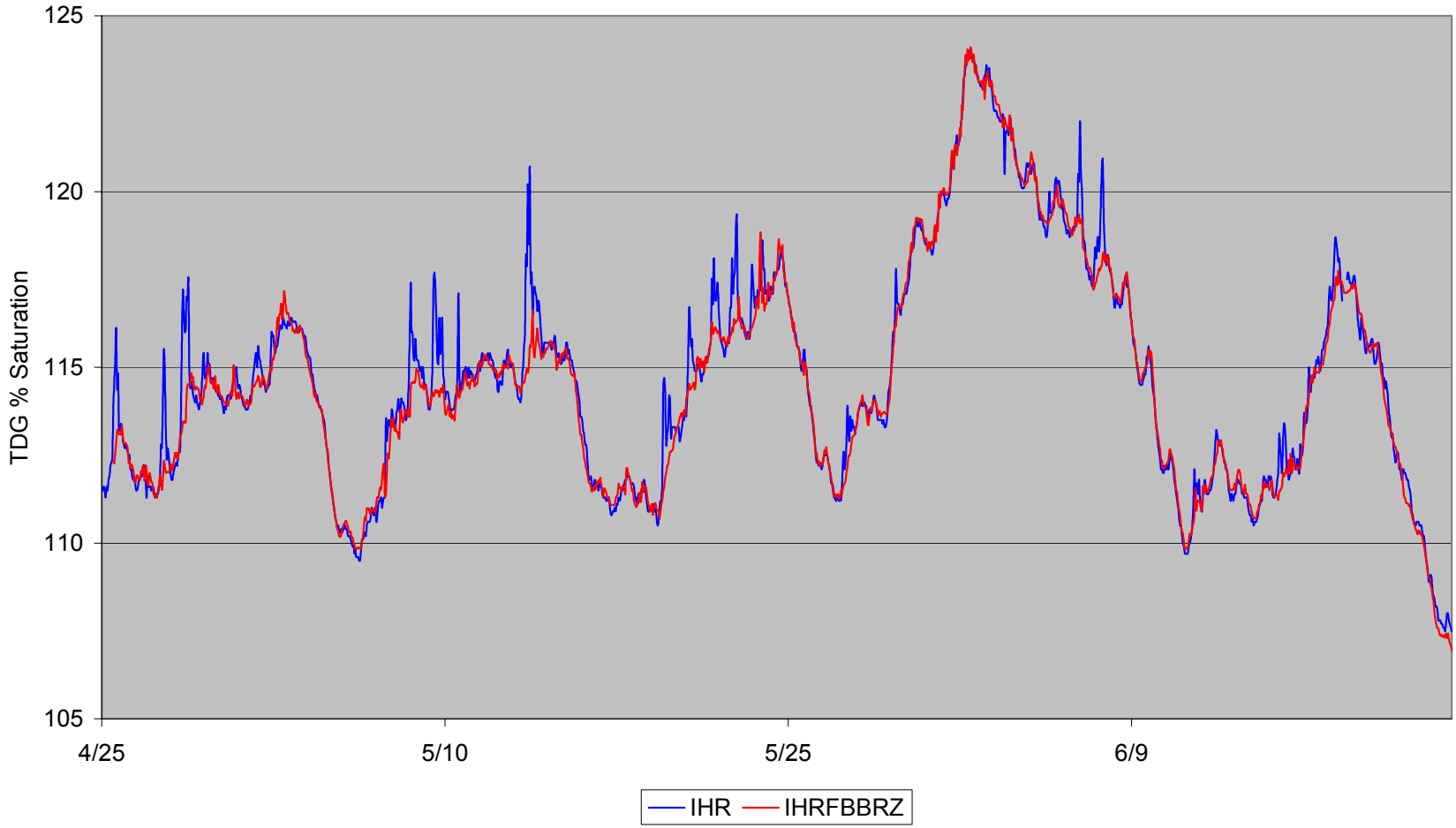

Figure 23. Ice Harbor Dam TDG Saturation IHR and IHRFBBRZ.

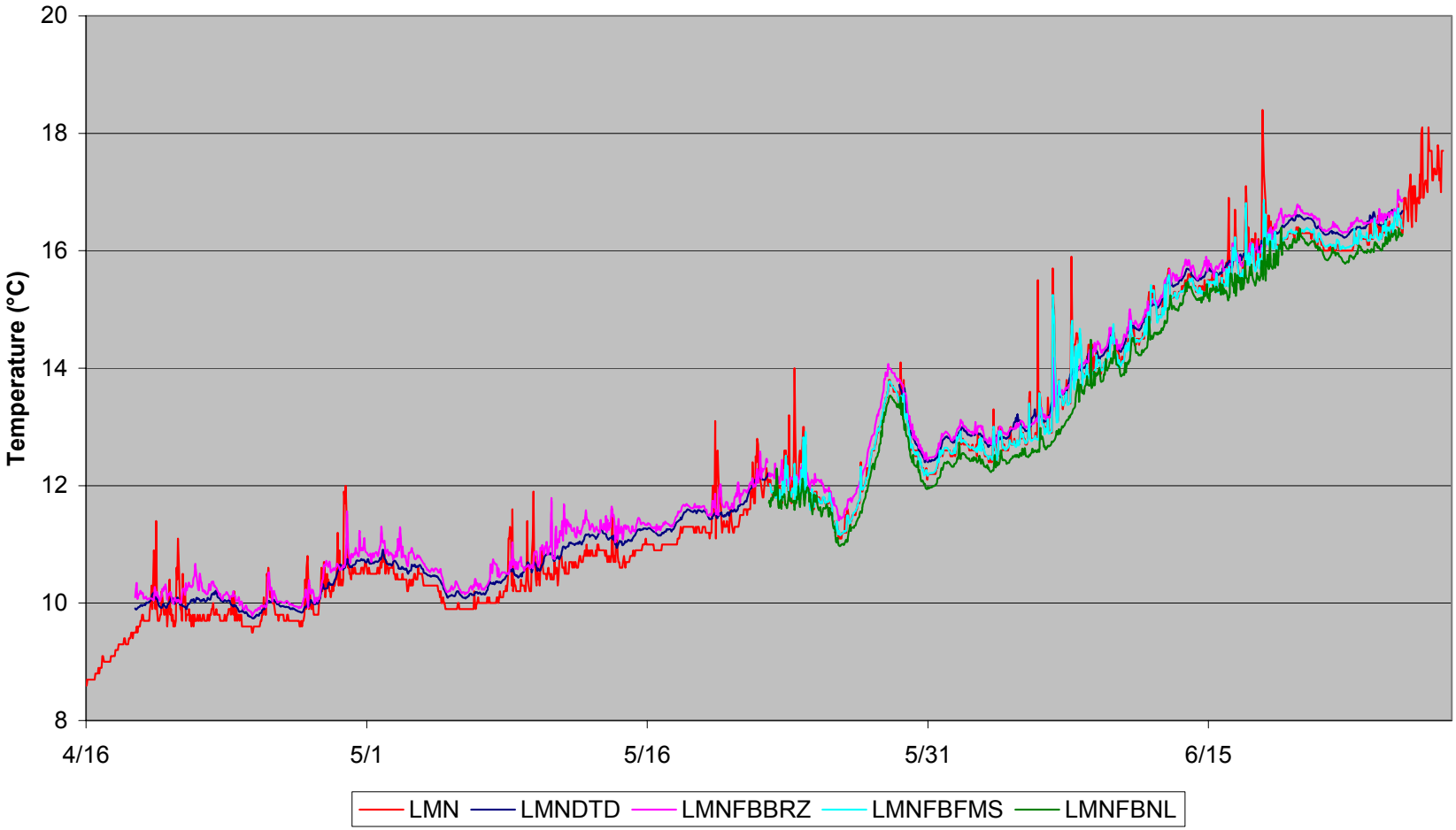

Figure 24. Lower Monumental Dam alternate TDG monitor station temperature.

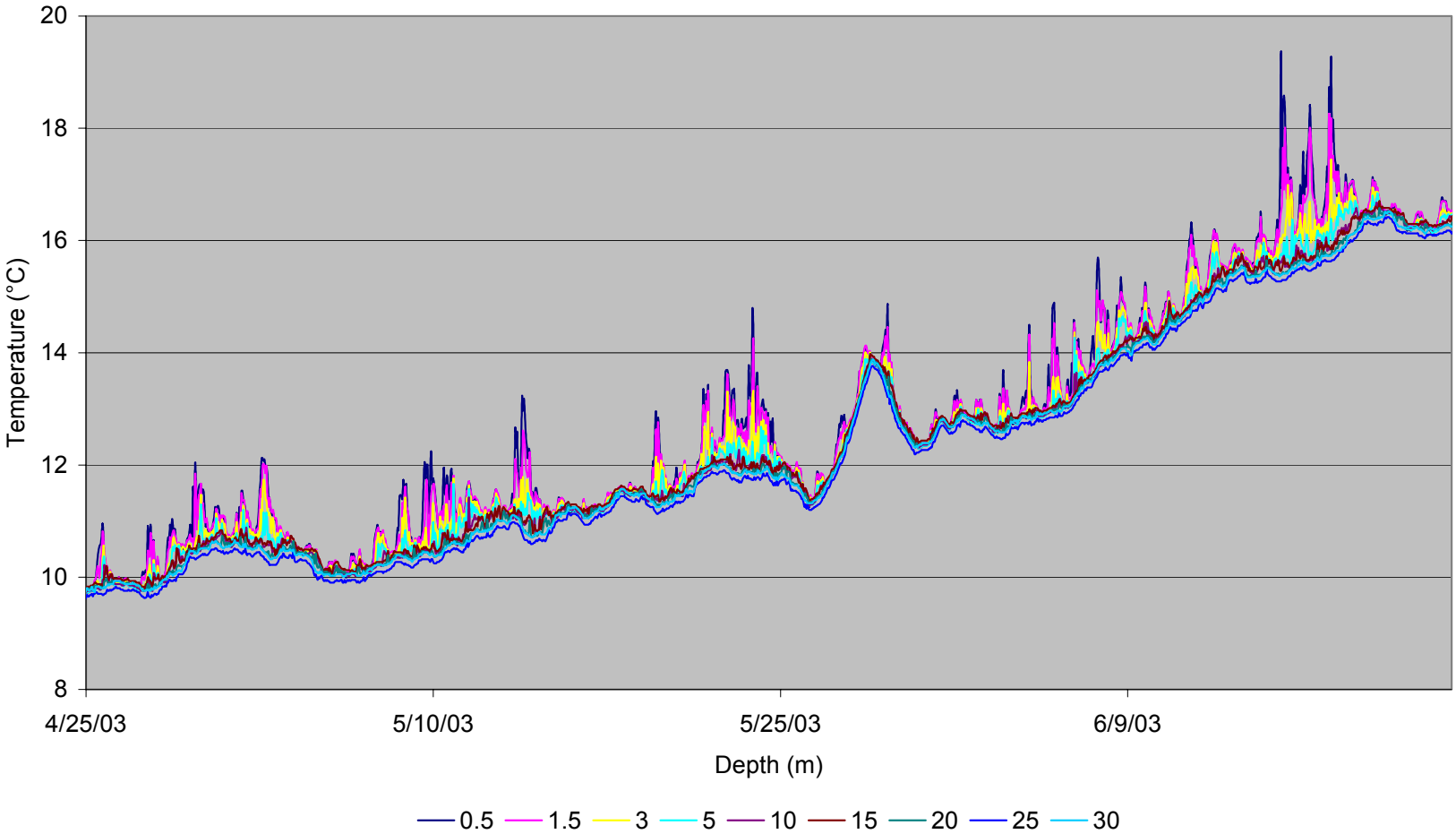

Figure 25. Lower Monumental Dam forebay thermal profile.

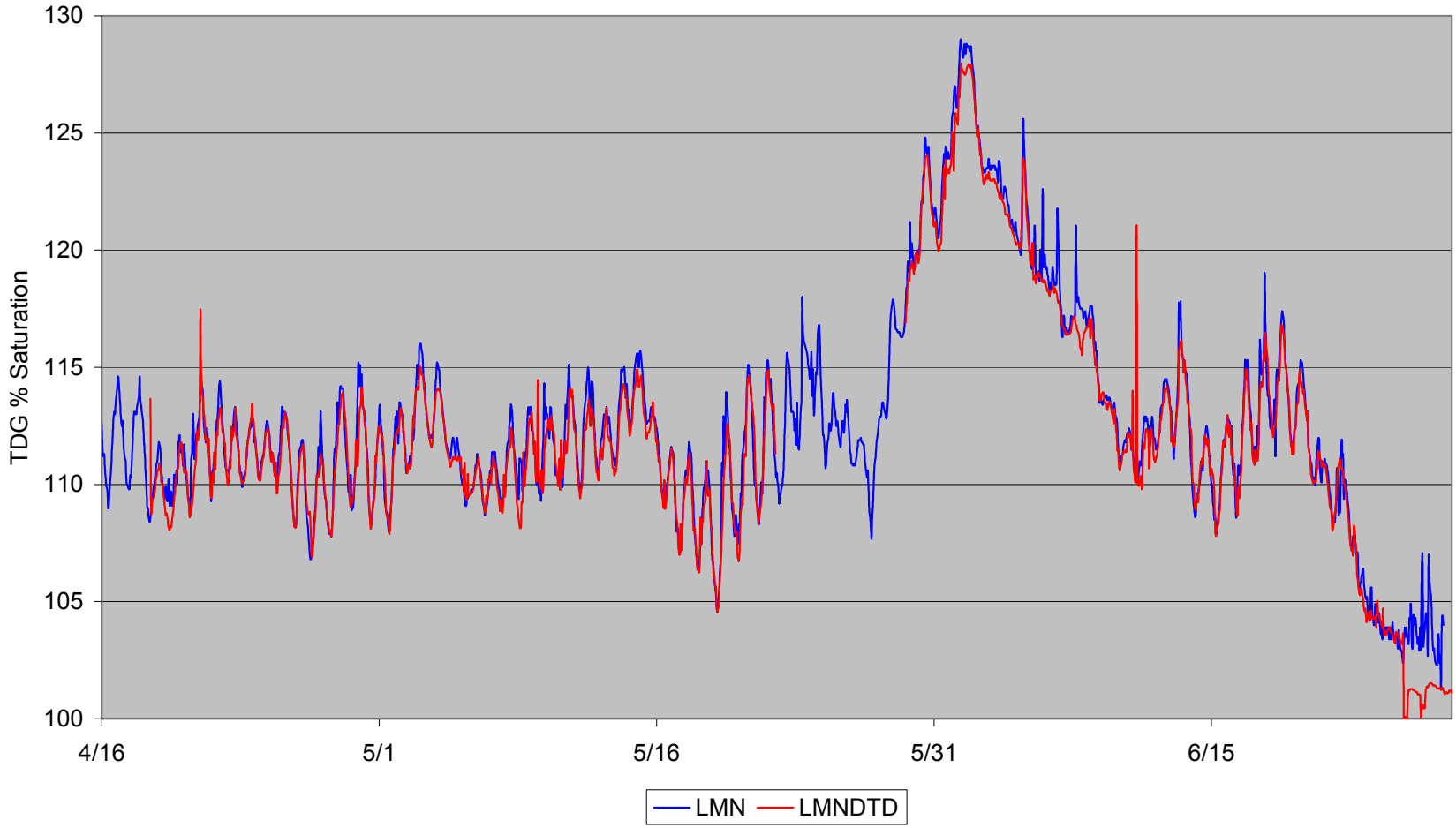

Figure 26. Lower Monumental Dam TDG Saturation LMN and LMNDTD.

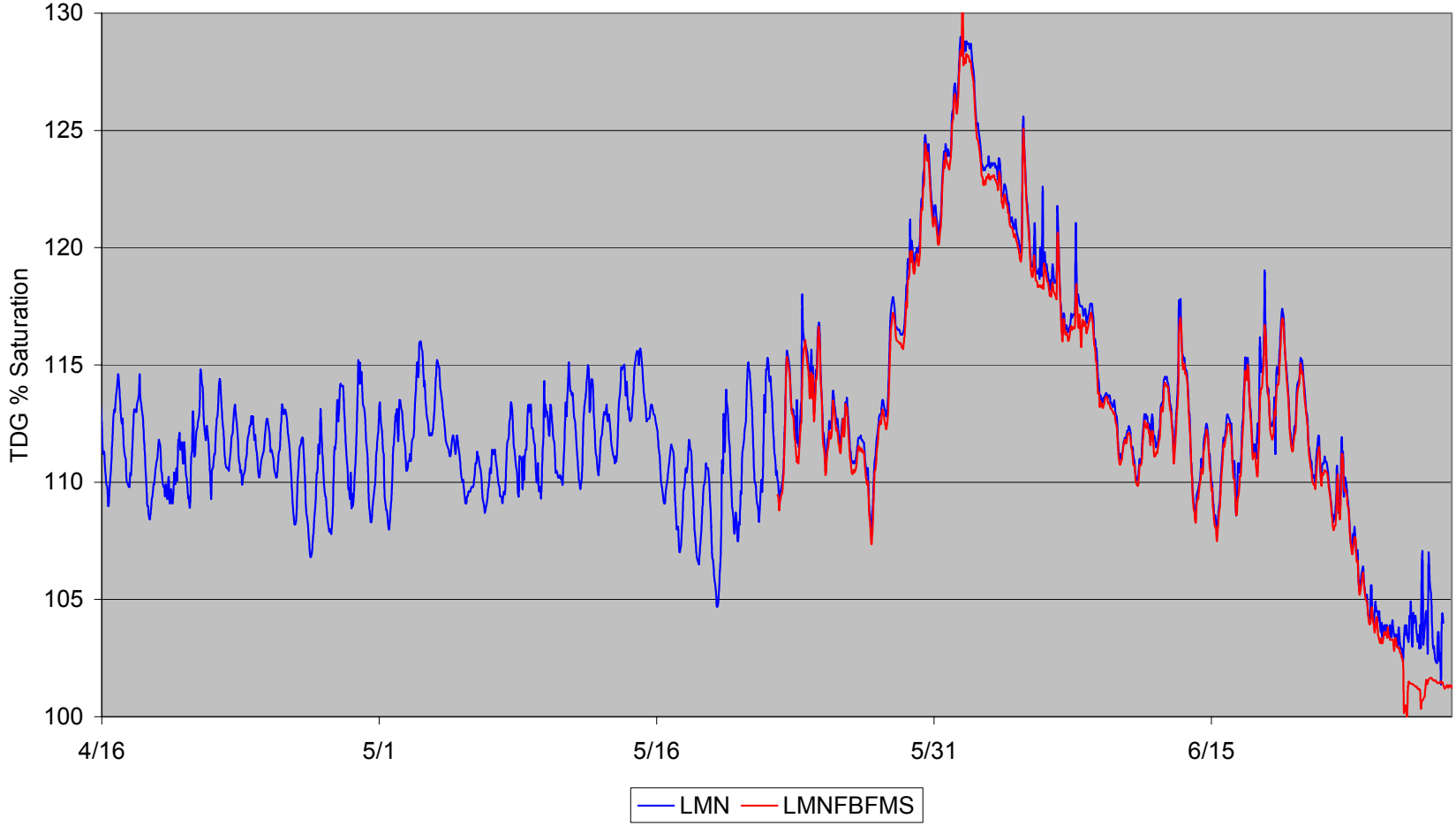

Figure 27. Lower Monumental Dam TDG Saturation LMN and LMNFBFMS.

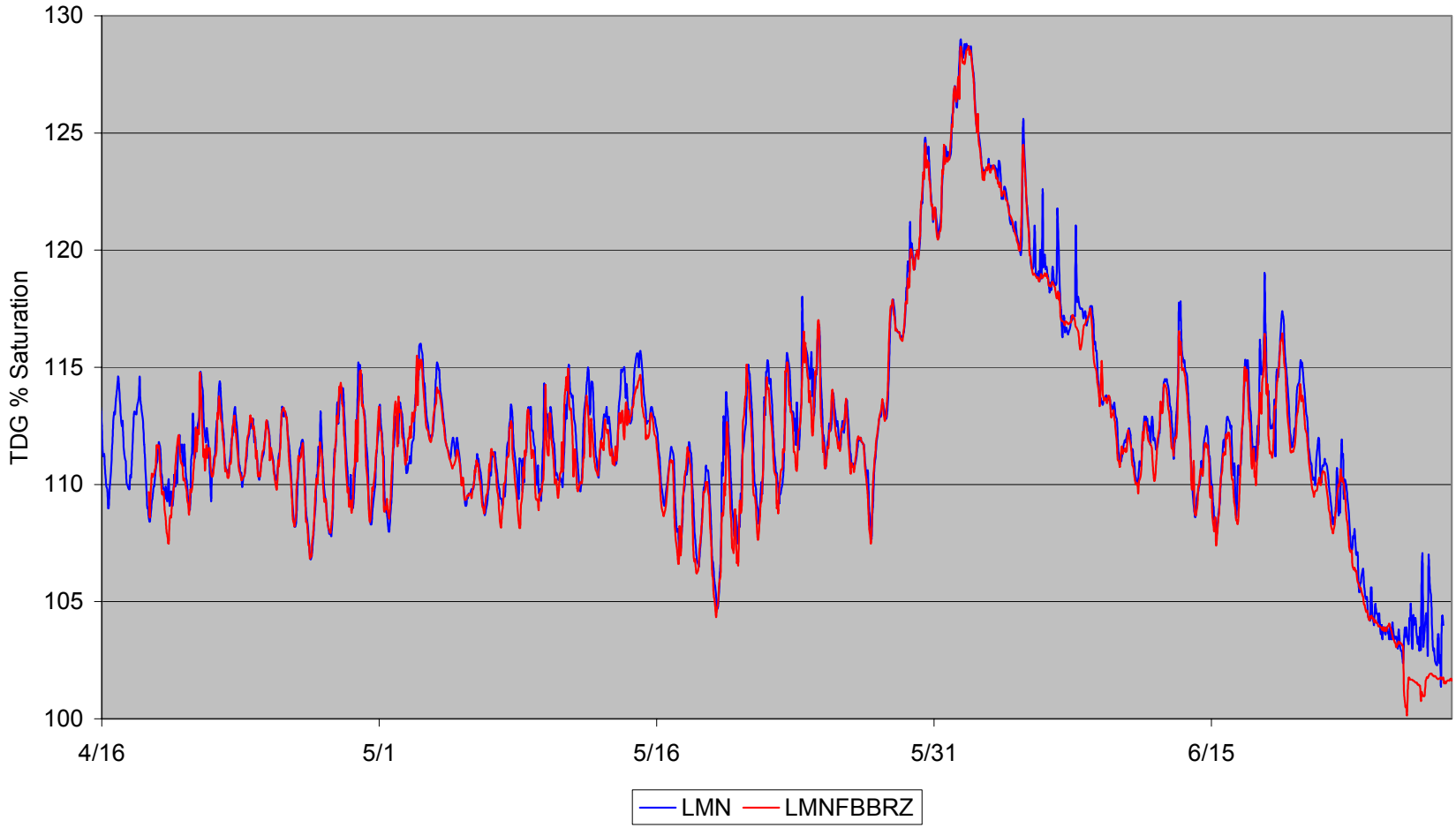

Figure 28. Lower Monumental Dam TDG Saturation LMN and LMNFBBRZ.

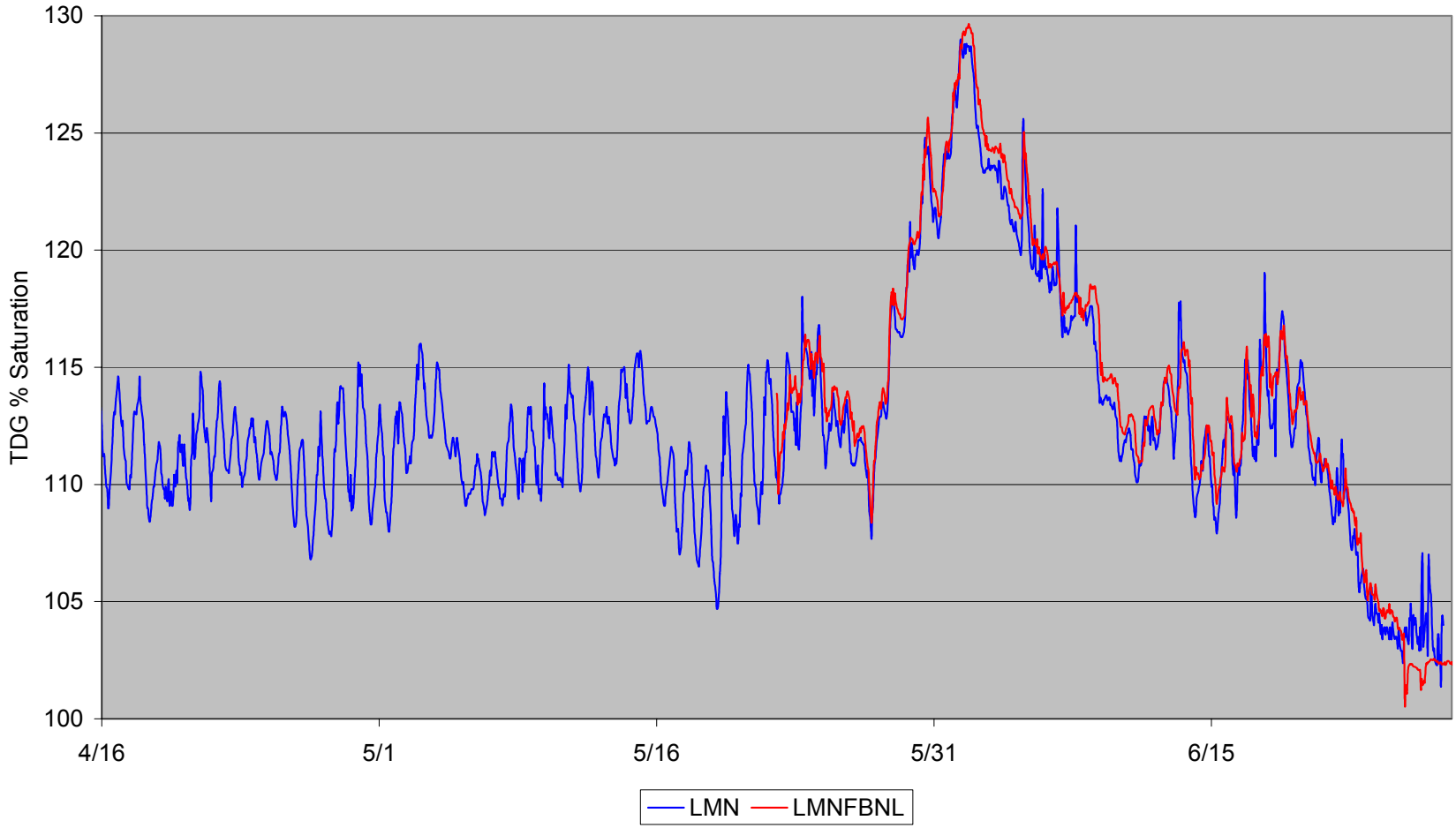

Figure 29. Lower Monumental Dam TDG Saturation LMN and LMNFBNL.

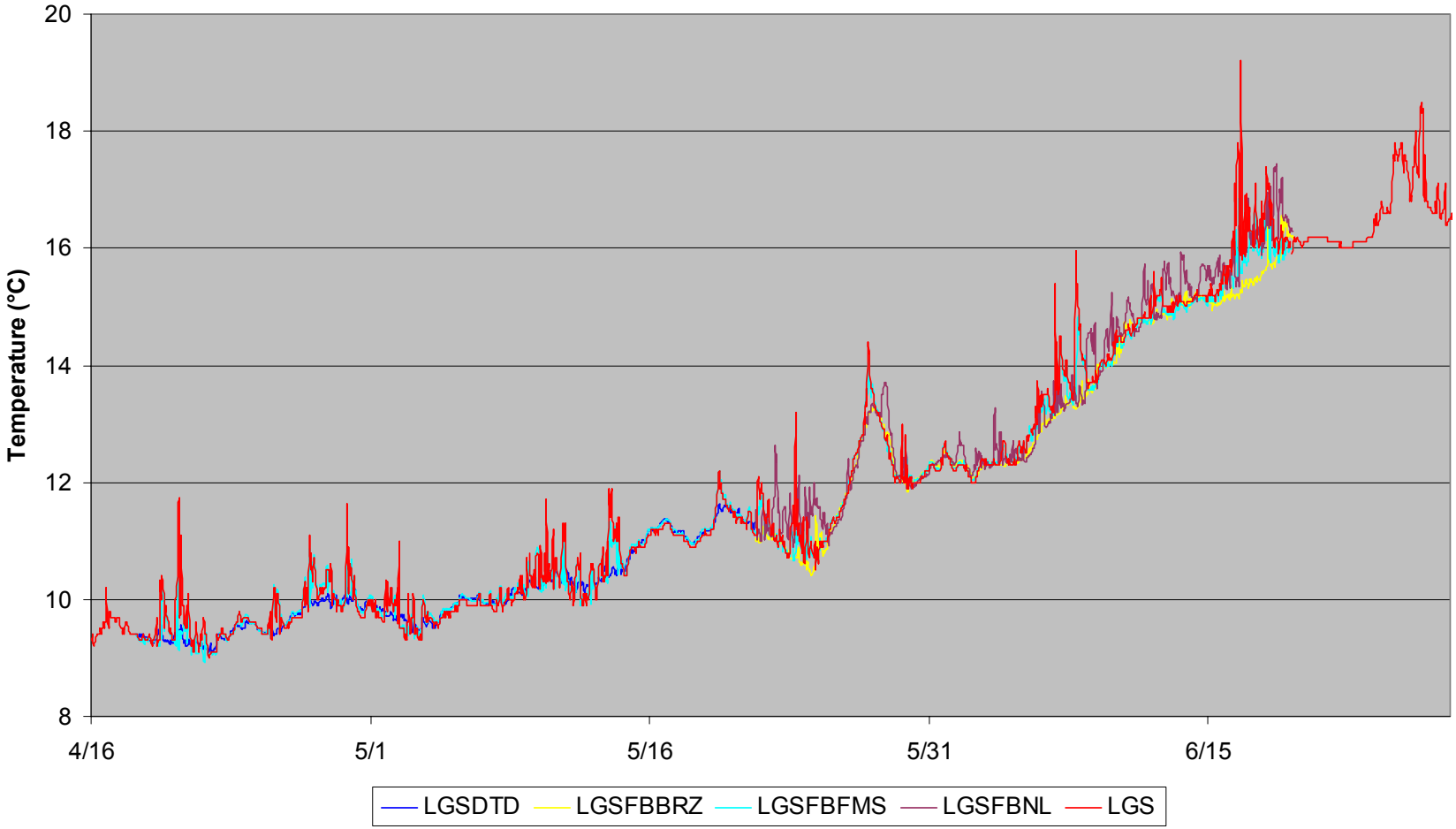

Figure 30. Little Goose Dam alternate TDG monitor station temperature.

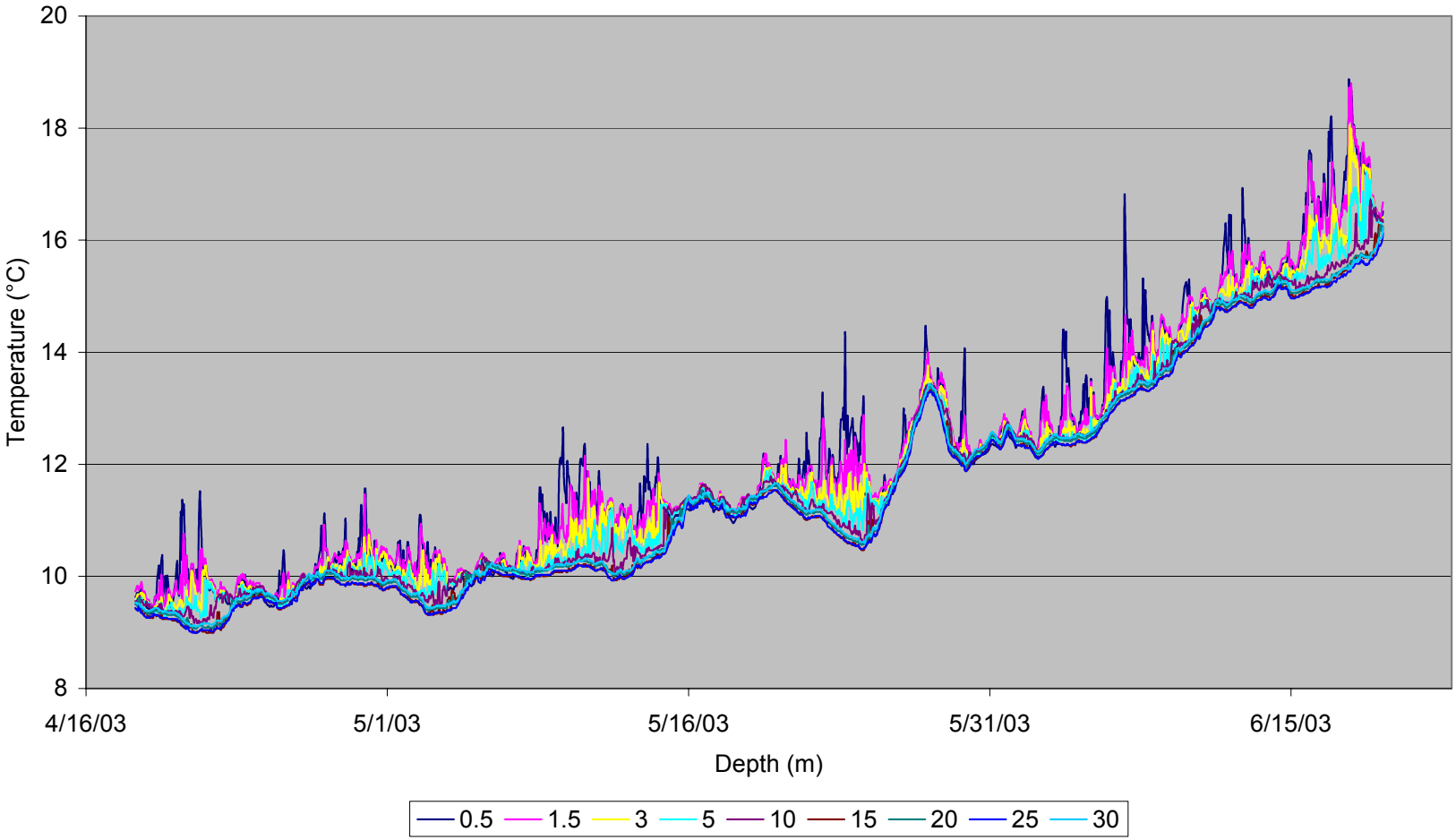

Figure 31. Little Goose Dam forebay thermal profile.

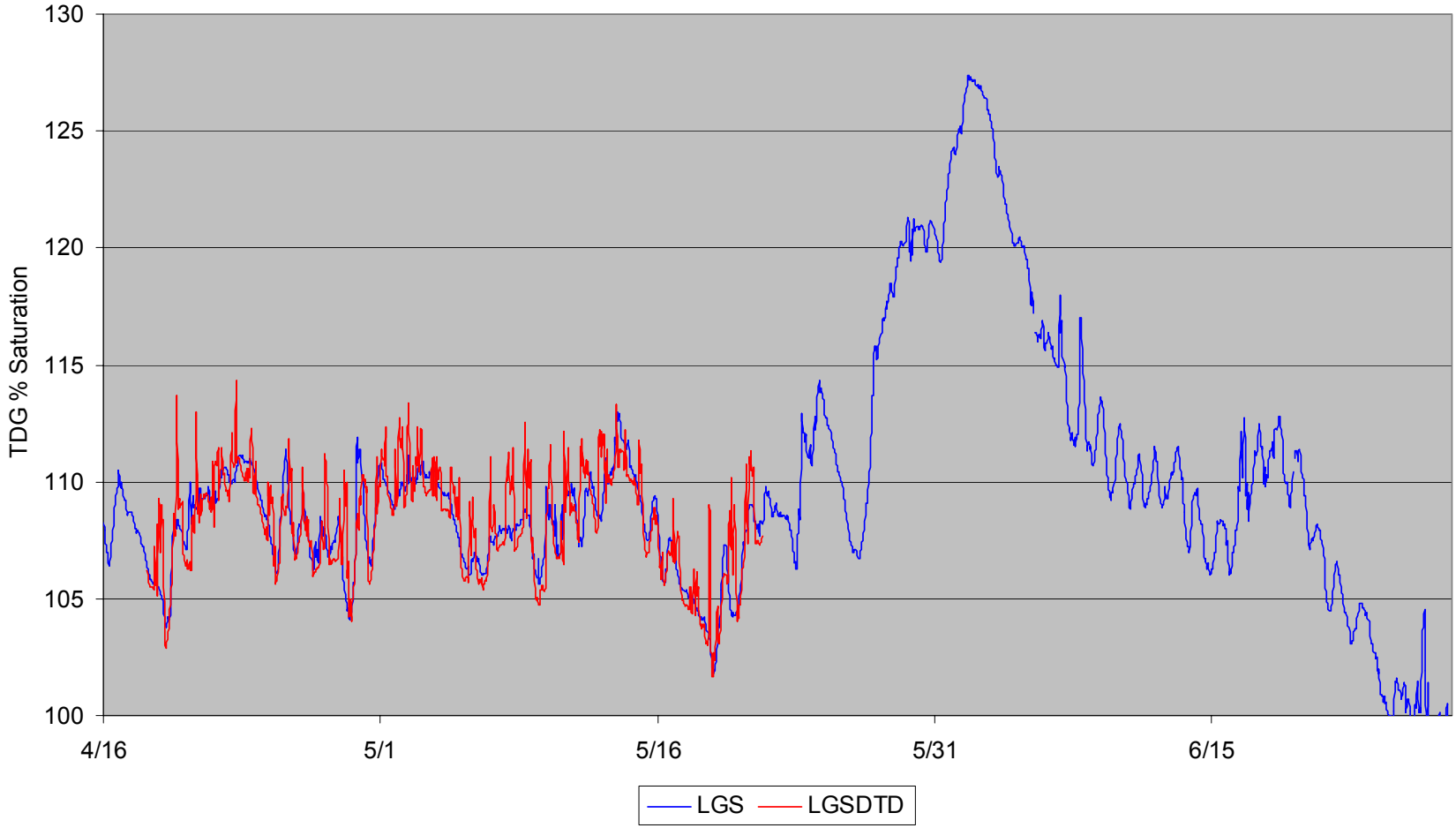

Figure 32. Little Goose Dam TDG Saturation LGS and LGSDTD.

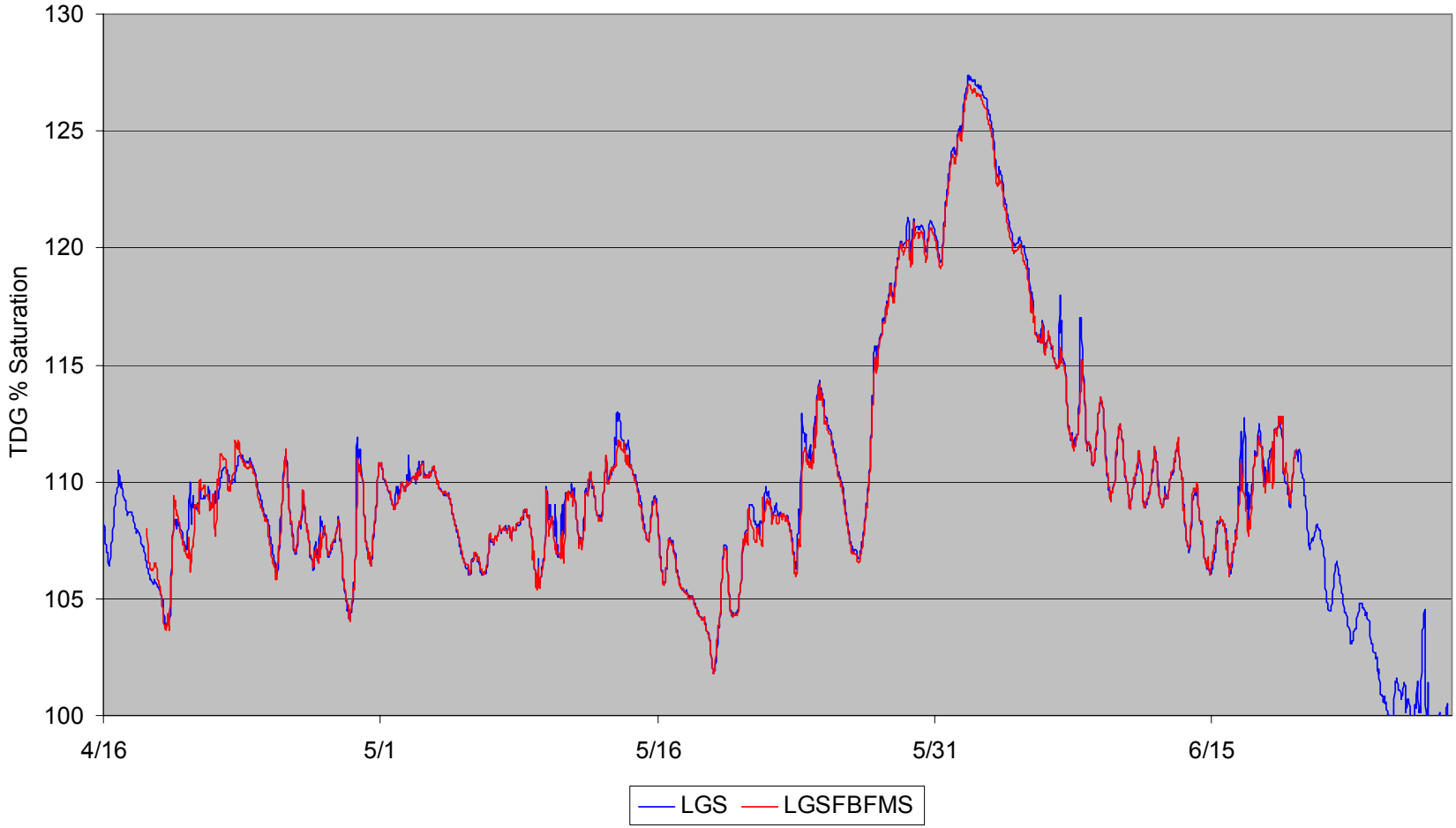

Figure 33. Little Goose Dam TDG Saturation LGS and LGSFBFMS.

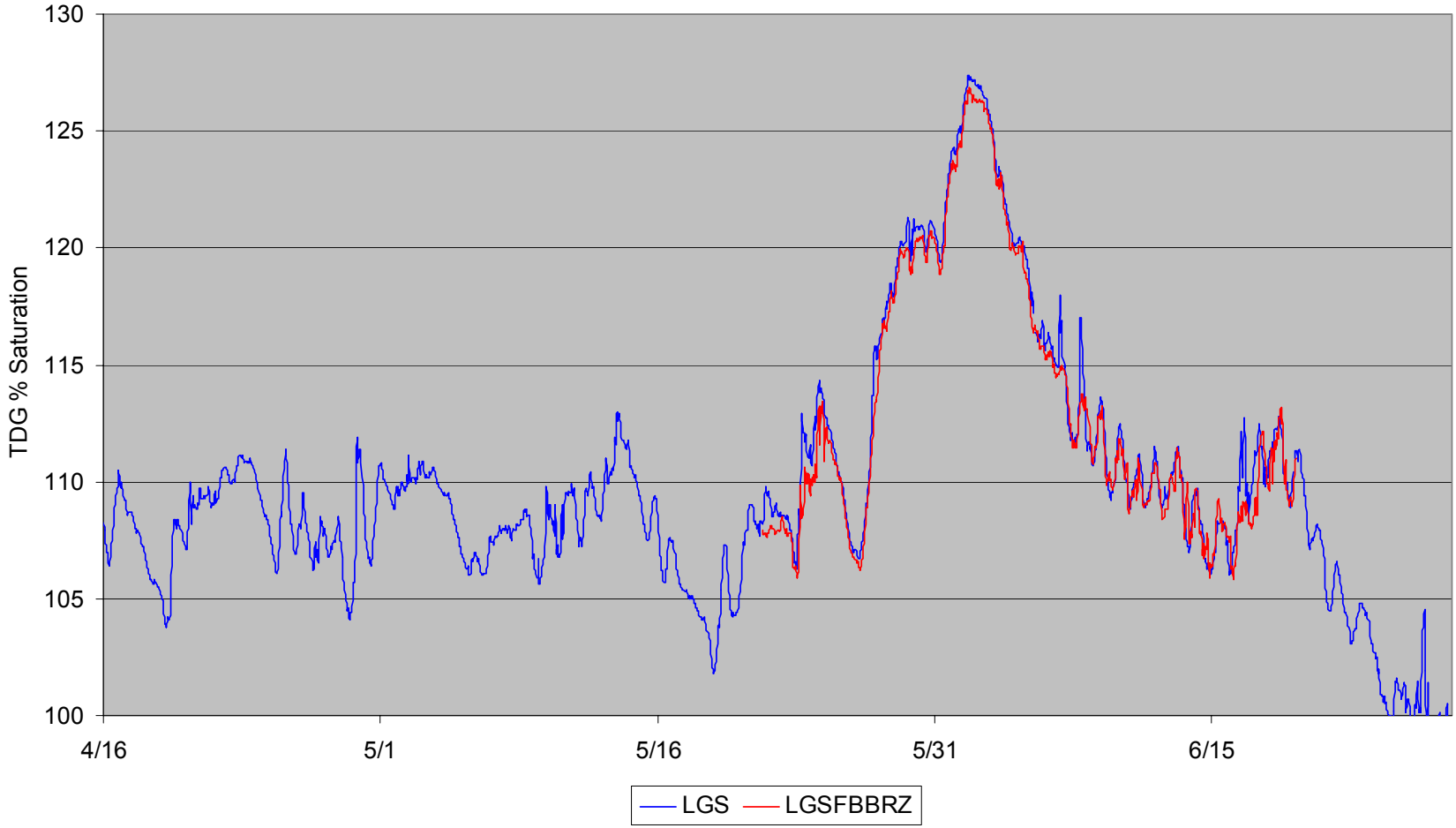

Figure 34. Little Goose Dam TDG Saturation LGS and LGSFBBRZ.

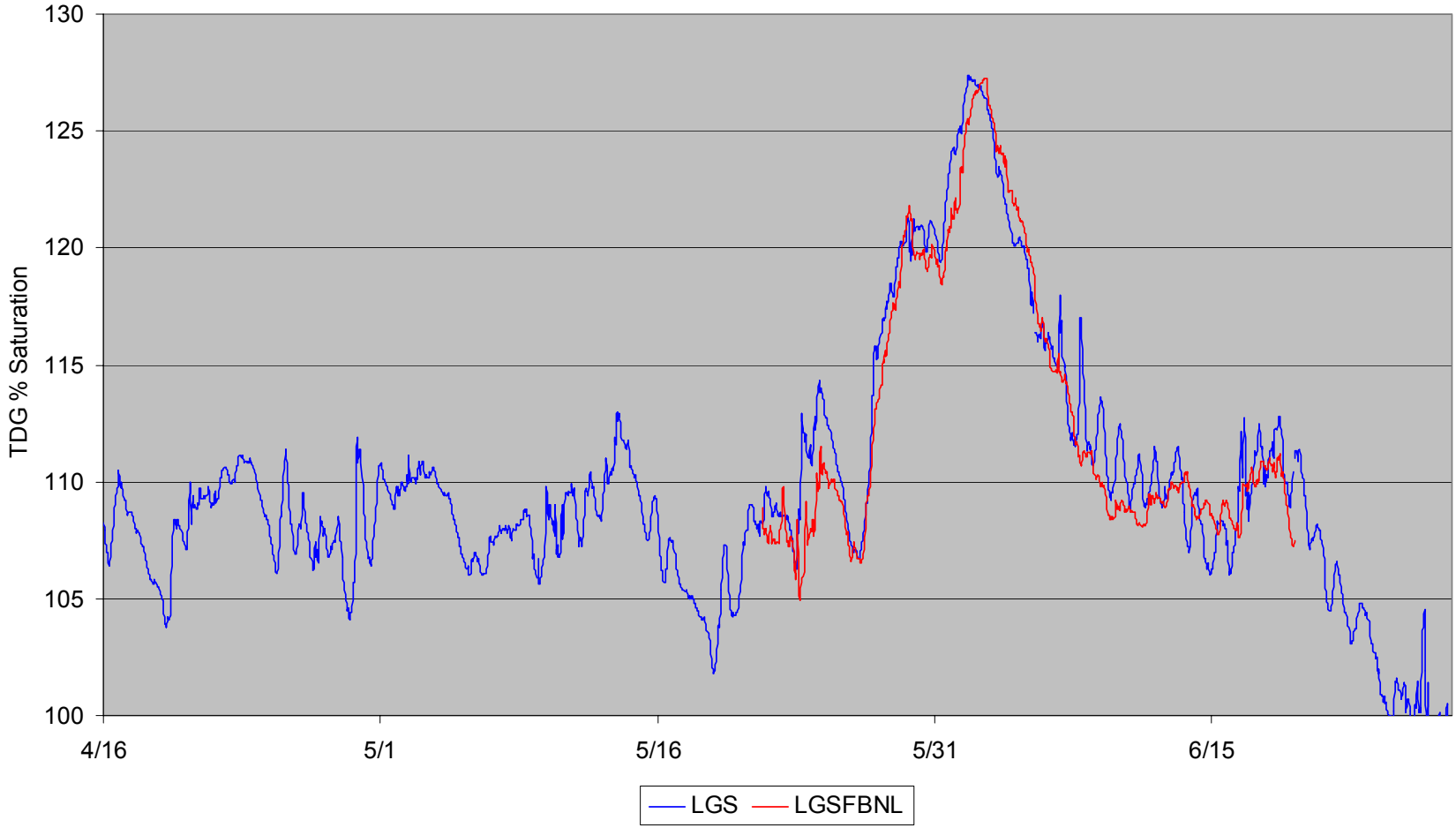

Figure 35. Little Goose Dam TDG Saturation LGS and LGSFBNL.

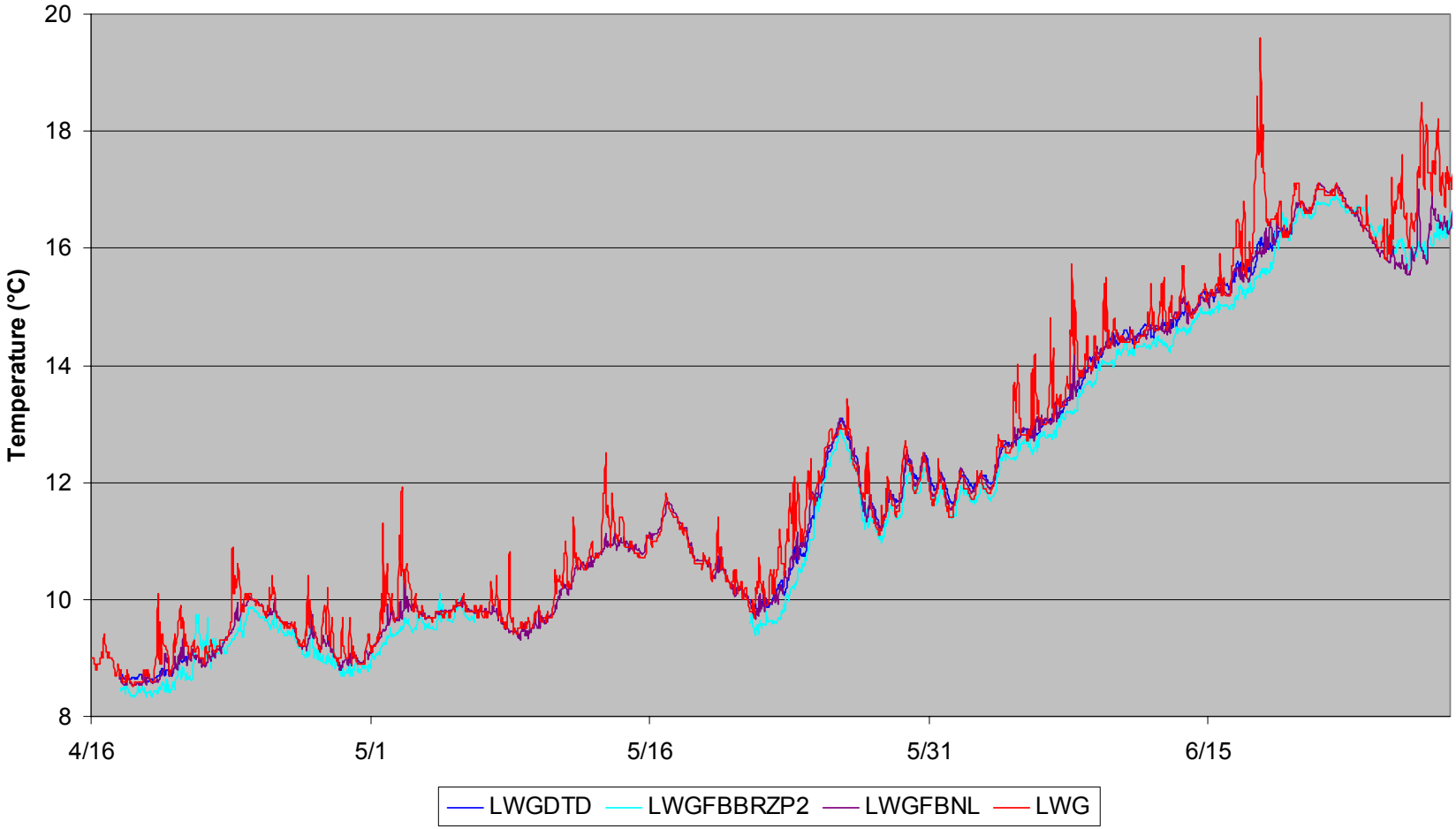

Figure 36. Lower Granite Dam alternate TDG monitor station temperature.

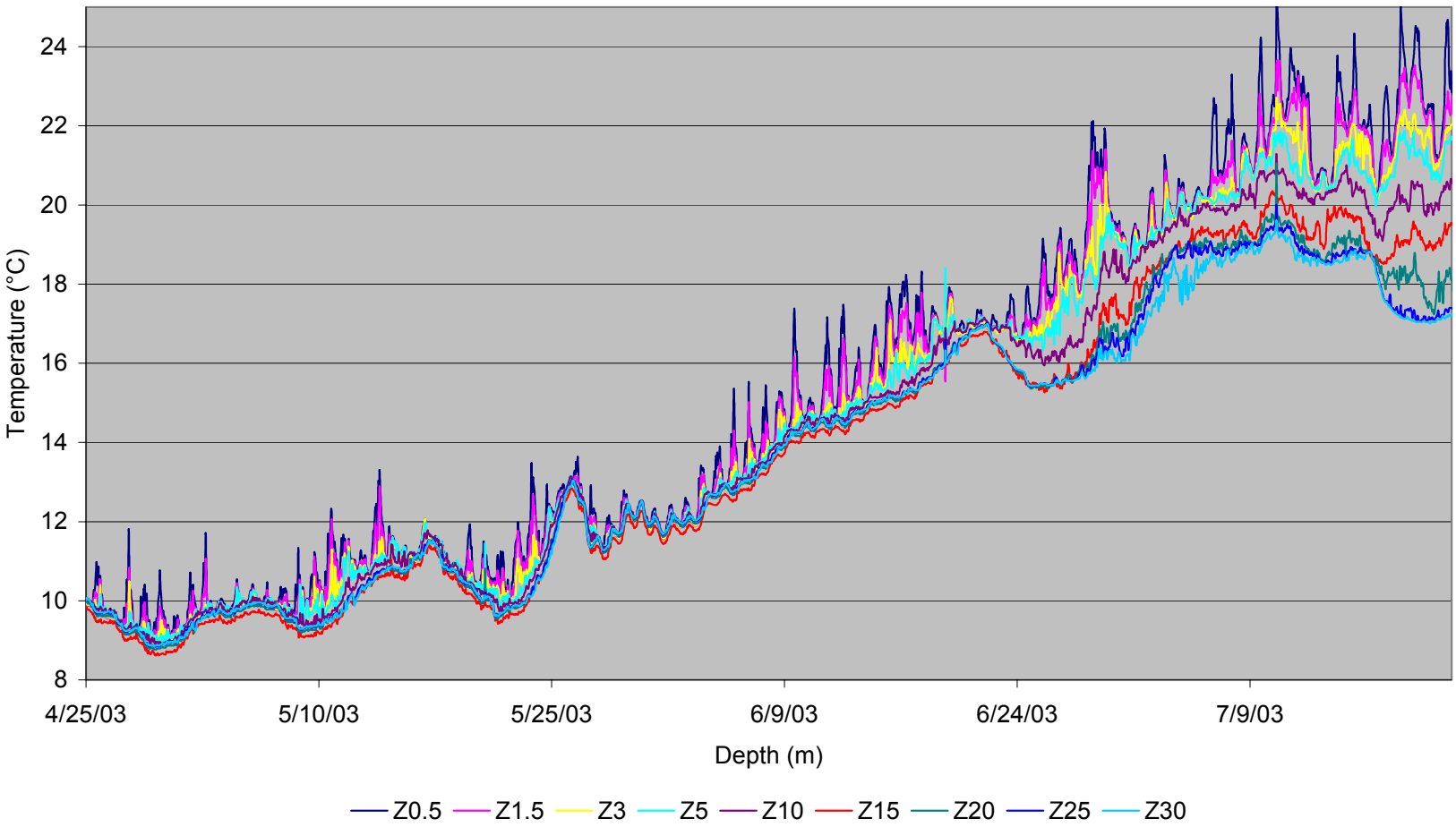

Figure 37. Lower Granite Dam forebay thermal profile.

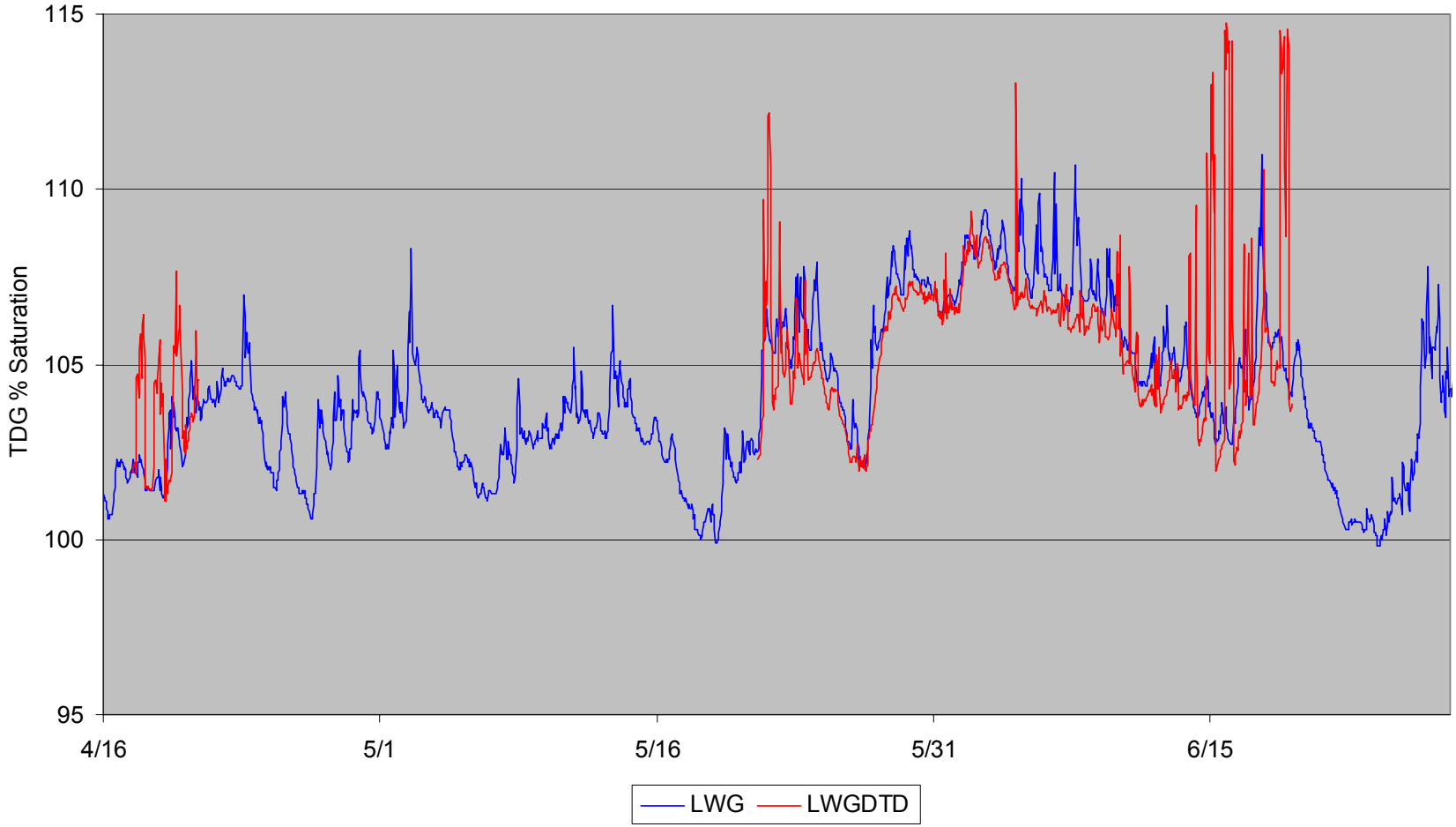

Figure 38. Lower Granite Dam TDG Saturation LWG and LWGDTD.

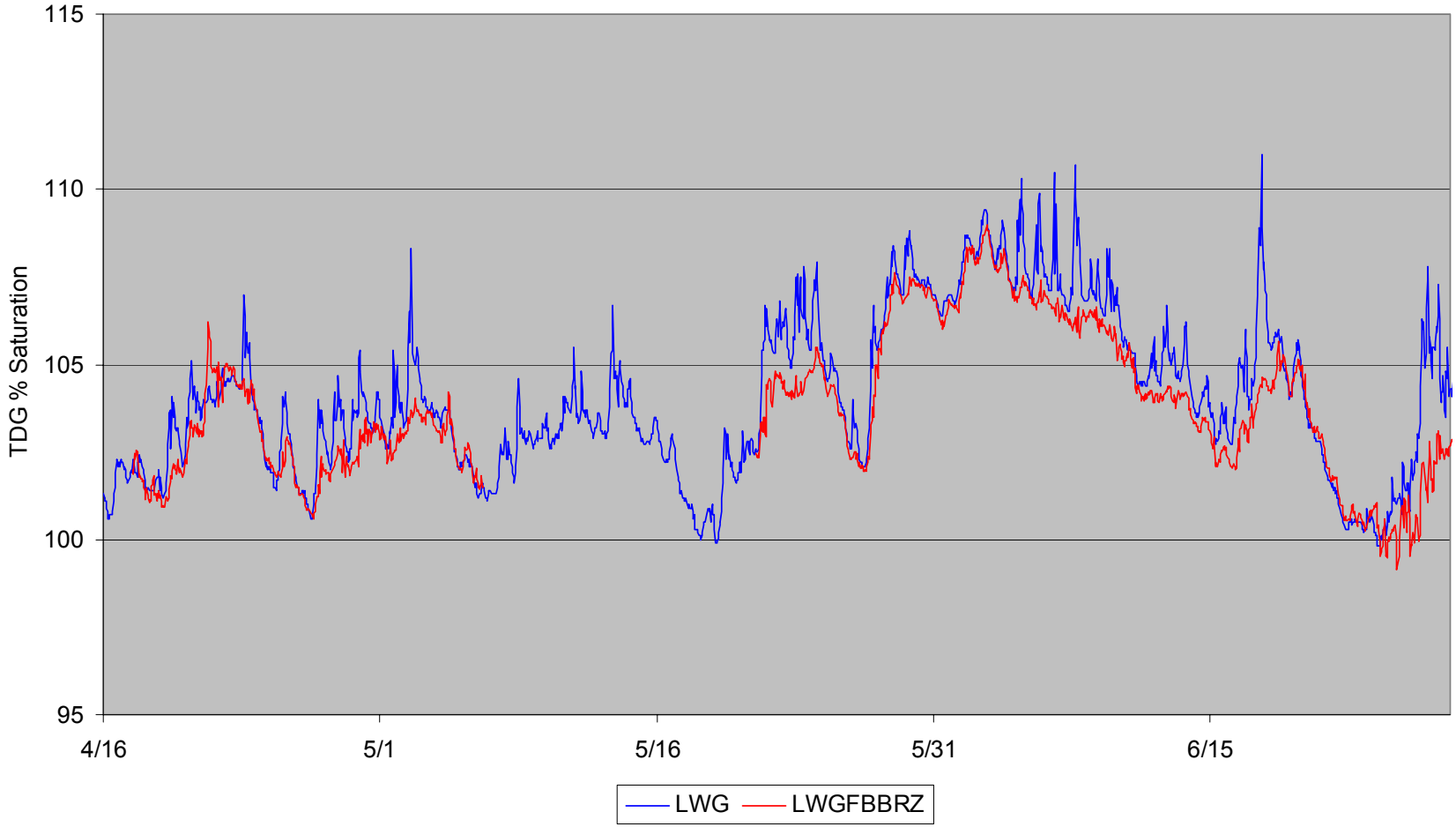

Figure 39. Lower Granite Dam TDG Saturation LWG and LWGFBBRZ.

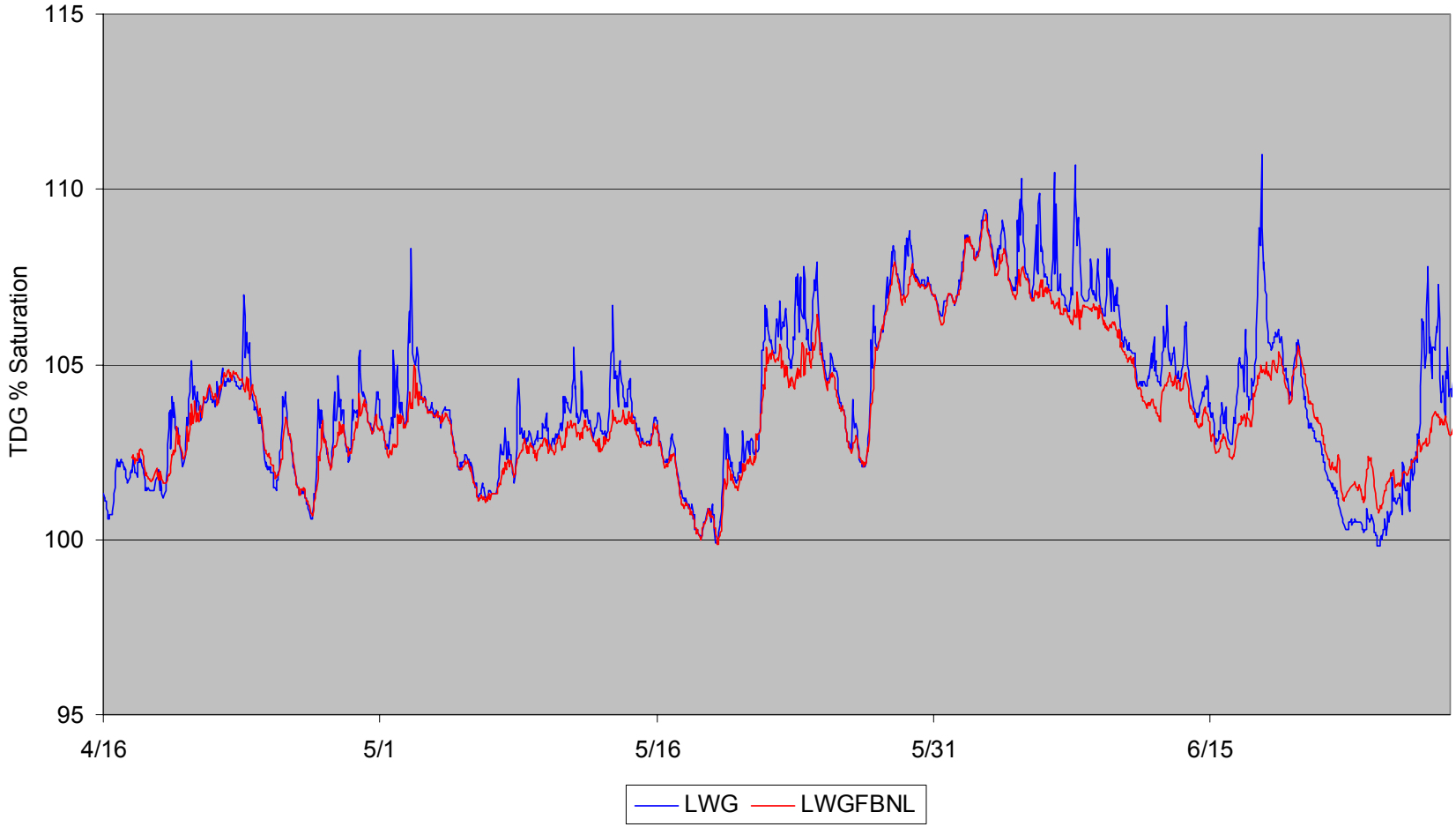

Figure 40. Lower Granite Dam TDG Saturation LWG and LWGFBNL.

DRAFT REPORT

TDG FOREBAY FIXED MONITORING STATION REVIEW AND EVALUATION FOR LOWER SNAKE RIVER PROJECTS AND MCNARY DAM

Report Figures

Table 1. Compliance parameter calculated for McNary Dam TDG stations.

DATE	MCQO	MCQW	MCNDTD	MCNFBBRZP1	MCNFBFMSP1	MCNFBFMSP2	IDSW
25-Apr-2003	109.27	110.70	109.05	109.94	109.40	111.04	114.63
26-Apr-2003	109.34	110.61	109.29	109.91	108.96	110.39	114.43
27-Apr-2003	111.88	111.44	109.53	109.88	111.52	110.96	114.81
28-Apr-2003	110.65	111.18	109.88	110.39	110.29	110.90	114.42
29-Apr-2003	113.94	113.77	111.04	111.31	113.16	113.17	114.85
30-Apr-2003	113.48	112.72	110.85	111.37	113.01	112.43	113.99
1-May-2003	114.75	114.63	111.50	111.91	114.17	113.70	113.61
2-May-2003	117.05	115.62	113.62	113.92	116.66	115.34	114.09
3-May-2003	114.30	115.94	113.75	114.31	113.79	115.66	114.45
4-May-2003	113.33	114.11	112.92	113.68	112.89	113.91	113.35
5-May-2003	109.03	108.86	107.99	108.52	108.70	108.63	112.32
6-May-2003	108.48	107.61	106.64	107.32	108.12	107.63	113.81
7-May-2003	110.81	109.34	108.80	109.25	110.47	109.38	114.44
8-May-2003	112.96	112.70	110.38	110.76	112.45	112.49	113.76
9-May-2003	112.72	113.72	111.06	111.35	112.32	113.66	112.78
10-May-2003	113.40	114.69	111.49	111.72	112.87	114.25	113.67
11-May-2003	114.23	114.18	112.13	112.46	113.69	114.38	114.08
12-May-2003	113.71	114.63	111.81	112.24	113.08	114.38	113.70
13-May-2003	114.68	114.83	111.19	111.54	113.88	114.23	113.42
14-May-2003	112.06	113.32	111.14	111.53	111.60	113.36	114.38
15-May-2003	111.05	111.13	110.72	111.40	110.58	111.30	114.75
16-May-2003	109.54	108.88	108.67	109.20	109.04	109.05	114.93
17-May-2003	108.03	107.41	107.42	107.82	107.60	107.65	113.99
18-May-2003	109.83	107.43	107.29	107.65	109.35	107.62	113.87
19-May-2003	110.19	110.47	107.95	108.26	109.81	109.94	114.33
20-May-2003	110.66	111.02	109.12	109.33	110.46	110.76	113.81
21-May-2003	116.33	113.58	111.81	111.93	115.68	113.29	113.98
22-May-2003	115.73	115.68	112.51	112.91	115.07	115.04	114.15
23-May-2003	115.90	117.10	114.01	114.30	115.33	116.86	115.37
24-May-2003	116.26	117.36	114.38	114.74	115.63	117.09	116.68
25-May-2003	116.73	116.58	115.06	115.43	116.01	116.45	116.68
26-May-2003	115.03	115.00	113.16	113.88	114.47	114.80	117.52
27-May-2003	113.16	113.98	111.19	111.55	112.69	113.66	119.84
28-May-2003	112.92	114.23	113.68	113.82	112.36	114.04	119.19
29-May-2003	116.81	116.16	114.96	115.58	116.06	116.04	121.14
30-May-2003	115.16	115.12	114.33	115.22	114.66	115.04	121.90
31-May-2003	114.25	113.98	113.68	114.75	114.09	113.89	125.64
1-Jun-2003	113.98	113.27	114.11	115.22	113.64	113.22	125.42
2-Jun-2003	118.14	117.03	116.86	117.95	117.88	117.06	119.62
3-Jun-2003	118.49	117.48	115.91	117.20	118.21	117.39	119.39
4-Jun-2003	117.73	116.64	115.50	116.72	117.37	116.59	119.22
5-Jun-2003	117.61	117.55	115.77	116.90	117.22	116.62	117.70
6-Jun-2003	119.34	117.25	115.98	116.87	118.91	116.91	116.68
7-Jun-2003	118.33	117.52	115.22	116.20	118.13	117.48	116.71
8-Jun-2003	117.15	116.89	115.77	116.56	116.96	116.91	116.95
9-Jun-2003	116.16	115.51	114.77	115.61	115.95	115.56	116.87
10-Jun-2003	113.61	113.25	112.07	112.97	113.42	113.50	115.63
11-Jun-2003	110.97	111.63	109.72	110.47	110.74	111.68	115.62
12-Jun-2003	111.63	112.50	111.07	111.55	111.42	112.58	117.17
13-Jun-2003	112.64	111.99	111.63	112.25	112.30	112.13	116.68
14-Jun-2003	111.40	110.68	110.37	111.16	111.22	110.79	114.51
15-Jun-2003	114.00	111.25	110.10	110.56	113.63	111.30	114.13
16-Jun-2003	113.02	114.55	111.40	111.90	112.57	113.99	114.83
17-Jun-2003	114.82	115.26	113.07	113.69	114.50	115.45	116.23
18-Jun-2003	113.94	114.36	113.61	114.42	113.72	114.67	113.87
Average	113.65	113.53	111.94	112.53	113.23	113.39	115.89
Count	55.00	55.00	55.00	55.00	55.00	55.00	55.00
Exceedance	17.00	17.00	8.00	12.00	15.00	17.00	4.00
% Exceedance	30.91	30.91	14.55	21.82	27.27	30.91	7.27

Table 2. Compliance parameter calculated for Ice Harbor Dam TDG Stations.

DATE	IHR	IHRDTD	IHRFBBRZ	IHRFBNL	IHRFBFMS	LMNW
25-Apr-2003						
26-Apr-2003	112.31	112.55	112.41		112.37	118.12
27-Apr-2003	113.07	112.67	112.00		112.26	119.22
28-Apr-2003	115.95	113.57	114.06		114.03	119.63
29-Apr-2003	114.91	113.99	114.67		114.26	119.07
30-Apr-2003	114.58	113.65	114.43		114.23	118.69
1-May-2003	115.00	114.01	114.49		114.52	119.08
2-May-2003	115.99	114.95	116.20		115.60	119.56
3-May-2003	116.28	115.61	116.39		116.13	118.53
4-May-2003	114.71	113.53	114.51		114.55	118.00
5-May-2003	110.75	110.62	110.90		110.68	117.42
6-May-2003	110.63	110.22	110.89		110.57	118.19
7-May-2003	113.55	112.28	113.11		112.87	117.81
8-May-2003	115.63	114.03	114.64		114.52	118.56
9-May-2003	116.11	114.25	114.40		114.41	118.31
10-May-2003	115.04	113.78	114.44		114.17	119.07
11-May-2003	115.22	114.21	115.18		114.91	119.24
12-May-2003	115.20	114.57	115.10		114.86	118.24
13-May-2003	117.89	114.80	115.38		115.42	119.21
14-May-2003	116.02	114.88	115.71		115.62	119.83
15-May-2003	115.38	114.45	115.30		115.10	118.72
16-May-2003	112.49	112.31	112.10		112.02	118.55
17-May-2003	111.53	110.98	111.64		111.54	118.59
18-May-2003	111.71	111.73	111.64		111.47	118.53
19-May-2003	113.53	113.59	112.13		112.33	119.98
20-May-2003	115.25	114.03	114.35		114.57	119.63
21-May-2003	116.76	115.30	115.90		115.74	120.40
22-May-2003	117.38	115.69	116.30		116.17	119.88
23-May-2003	117.53	116.04	117.09		116.66	119.92
24-May-2003	117.88	116.95	118.00		117.57	120.36
25-May-2003	116.23	115.52	116.16		116.05	118.19
26-May-2003	112.89	112.13	112.92		112.67	119.20
27-May-2003	113.24	111.81	112.65		112.63	121.60
28-May-2003	113.99	113.18	114.00		113.86	123.49
29-May-2003	116.43	115.40	116.11		116.18	126.16
30-May-2003	118.93	118.40	119.10	118.96	119.01	126.32
31-May-2003	119.69	119.06	119.78	119.62	119.67	128.98
1-Jun-2003	123.12	122.36	123.15	122.99	123.20	127.49
2-Jun-2003	123.53	122.86	123.50	123.35	123.42	124.00
3-Jun-2003	122.13	121.42	122.35	122.22	122.08	121.58
4-Jun-2003	120.70	119.75	120.68	120.59	120.39	119.91
5-Jun-2003	120.00	118.99	119.71	119.51	119.53	119.36
6-Jun-2003	119.73	118.47	119.35	119.21	119.21	119.26
7-Jun-2003	118.92	117.42	118.05	117.87	117.85	118.34
8-Jun-2003	117.49	116.70	117.56	117.48	117.28	117.57
9-Jun-2003	115.47	114.95	115.54	115.48	115.45	114.63
10-Jun-2003	112.78	112.55	112.96	112.94	112.80	116.78
11-Jun-2003	111.21	110.86	111.02	110.75	110.93	117.76
12-Jun-2003	112.61	112.71	112.46	112.30	112.39	118.27
13-Jun-2003	111.96	112.59	112.08	111.95	111.96	118.36
14-Jun-2003	111.44	111.08	111.48	111.35	111.43	118.97
15-Jun-2003	112.55	112.32	112.00	111.85	111.87	119.10
16-Jun-2003	113.95	114.05	114.02	113.91	114.04	119.10
17-Jun-2003	117.20	116.32	116.53	116.56	116.80	121.00
18-Jun-2003	117.81	117.11	117.38	117.22	117.49	121.00
Average	115.60	114.76	115.26	116.81	115.14	119.75
Count	54.00	54.00	54.00	20.00	54.00	54.00
Exceedance	33.00	19.00	26.00	4.00	24.00	12.00
% Exceedance	61.11	35.19	48.15	20.00	44.44	22.22

Table 3. Compliance parameter calculated for Lower Monumental Dam TDG stations.

DATE	LMN	LMNDTD	LMNFBBRZ	LMNFBFMS	LMNFBNL	LGSW
25-Apr-2003						
26-Apr-2003						
27-Apr-2003						
28-Apr-2003						
29-Apr-2003						
30-Apr-2003						
1-May-2003						
2-May-2003						
3-May-2003						
4-May-2003						
5-May-2003						
6-May-2003						
7-May-2003						
8-May-2003						
9-May-2003						
10-May-2003						
11-May-2003						
12-May-2003						
13-May-2003						
14-May-2003						
15-May-2003						
16-May-2003						
17-May-2003						
18-May-2003						
19-May-2003						
20-May-2003						
21-May-2003						
22-May-2003						
23-May-2003	115.21	114.42	114.42	114.55	114.40	115.13
24-May-2003	115.88	115.60	115.60	115.52	116.02	115.09
25-May-2003	112.93	112.79	112.79	112.50	114.15	114.27
26-May-2003	112.61	112.57	112.57	112.37	113.51	114.70
27-May-2003	111.65	111.72	111.72	111.16	112.28	117.78
28-May-2003	116.81	116.81	116.81	115.66	117.12	119.03
29-May-2003	119.48	119.53	119.06	118.89	119.90	122.90
30-May-2003	123.67	123.24	123.37	123.23	124.35	123.41
31-May-2003	124.13	123.39	124.12	123.72	124.28	126.61
1-Jun-2003	128.66	127.75	128.42	129.05	129.34	125.16
2-Jun-2003	126.46	126.11	126.31	125.90	127.75	121.91
3-Jun-2003	123.57	122.91	123.34	122.99	124.32	124.59
4-Jun-2003	122.72	122.08	122.52	122.20	123.11	117.03
5-Jun-2003	120.77	119.93	119.99	119.90	121.60	116.54
6-Jun-2003	119.63	118.38	118.67	119.06	119.65	115.94
7-Jun-2003	117.93	116.82	117.01	117.07	118.04	114.77
8-Jun-2003	117.35	116.72	117.05	116.85	118.24	113.45
9-Jun-2003	113.65	113.64	113.91	113.43	114.69	113.51
10-Jun-2003	111.92	112.75	111.71	111.79	112.88	114.79
11-Jun-2003	112.64	112.00	112.13	112.27	113.07	117.43
12-Jun-2003	113.95	113.71	113.65	113.72	114.61	115.58
13-Jun-2003	115.79	115.16	115.05	115.42	115.64	114.04
14-Jun-2003	111.52	111.46	111.22	111.31	111.92	114.74
15-Jun-2003	111.72	111.77	111.39	111.52	111.93	115.66
16-Jun-2003	113.51	113.16	113.25	113.10	113.08	115.67
17-Jun-2003	115.50	114.57	114.21	114.71	115.15	115.77
18-Jun-2003	115.93	115.63	115.33	115.50	116.14	116.23
Average	117.24	116.84	116.88	116.79	117.67	117.47
Count	27.00	27.00	27.00	27.00	27.00	27.00
Exceedance	17.00	15.00	15.00	15.00	16.00	6.00
% Exceedance	62.96	55.56	55.56	55.56	59.26	22.22

Table 4. Compliance parameter calculated for Little Goose Dam TDG Stations.

DATE	LGS	LGSDTD	LGSFBBRZ	LGSFBFMS	LGSFBNL	LGNW
25-Apr-2003		109.21				
26-Apr-2003		109.43				
27-Apr-2003		107.69				
28-Apr-2003		108.56				
29-Apr-2003		109.03				
30-Apr-2003		109.91				
1-May-2003		110.93				
2-May-2003		111.89				
3-May-2003		111.07				
4-May-2003		110.17				
5-May-2003		109.00				
6-May-2003		107.32				
7-May-2003		109.18				
8-May-2003		110.25				
9-May-2003		108.02				
10-May-2003		109.52				
11-May-2003		110.40				
12-May-2003		110.99				
13-May-2003		111.50				
14-May-2003		110.81				
15-May-2003		109.52				
16-May-2003		107.30				
17-May-2003		106.27				
18-May-2003		105.55				
19-May-2003		106.42				
20-May-2003		108.51				
21-May-2003		110.62				
22-May-2003	109.03		108.15	108.75	108.49	115.37
23-May-2003	109.98		108.54	109.12	107.51	110.73
24-May-2003	113.49		112.11	113.23	110.00	110.27
25-May-2003	112.48		111.72	112.25	110.28	116.68
26-May-2003	108.62		108.32	108.44	108.01	123.06
27-May-2003	114.18		112.44	113.77	112.07	126.99
28-May-2003	118.37		117.85	118.19	117.20	127.65
29-May-2003	120.59		119.91	120.32	121.10	127.67
30-May-2003	120.98		120.51	120.71	119.85	131.13
31-May-2003	122.72		122.17	122.47	120.49	133.54
1-Jun-2003	126.73		126.25	126.41	124.96	131.85
2-Jun-2003	127.03		126.36	126.64	127.03	126.91
3-Jun-2003	124.30		123.99	123.90	125.08	124.09
4-Jun-2003	120.63		120.19	120.22	122.11	117.99
5-Jun-2003	118.19		117.38	117.75	119.37	117.21
6-Jun-2003	116.28		115.34	115.90	115.44	117.62
7-Jun-2003	114.44		113.73	113.69	113.73	117.53
8-Jun-2003	113.22		113.15	113.31	111.23	117.74
9-Jun-2003	112.18		111.77	112.34	109.49	117.75
10-Jun-2003	111.11		110.91	111.22	108.97	117.54
11-Jun-2003	110.73		110.37	110.89	109.18	116.78
12-Jun-2003	110.36		110.15	110.35	109.70	117.53
13-Jun-2003	110.76		110.48	110.81	110.12	117.52
14-Jun-2003	109.03		108.68	109.14	109.03	117.83
15-Jun-2003	108.20		108.36	108.21	108.96	119.12
16-Jun-2003	110.49		108.77	109.32	109.27	119.34
17-Jun-2003	111.56		111.27	111.32	110.68	118.73
18-Jun-2003	112.30		112.27	112.41	110.89	118.98
Average	114.93	109.22	114.33	114.68	113.94	120.54
Count	28.00	34.00	28.00	28.00	28.00	28.00
Exceedance	10.00	0.00	10.00	10.00	10.00	9.00
% Exceedance	35.71	0.00	35.71	35.71	35.71	32.14

Table 5. Compliance parameter calculated for Lower Granite Dam TDG Stations.

DATE	LWG	LWGDTD	LWGFBBRZP2	LWGFBNL	DWQI
25-Apr-2003	103.10		102.35	102.75	109.05
26-Apr-2003	102.42		102.27	102.47	109.00
27-Apr-2003	103.08		101.64	102.32	108.74
28-Apr-2003	103.81		102.35	102.99	109.10
29-Apr-2003	104.04		102.46	103.35	108.77
30-Apr-2003	104.07		103.25	103.67	108.08
1-May-2003	104.06		102.96	103.03	107.62
2-May-2003	105.76		103.58	104.08	109.25
3-May-2003	104.38		103.64	104.06	108.97
4-May-2003	103.71		103.48	103.54	108.56
5-May-2003	102.41		102.59	102.29	108.63
6-May-2003	101.58		101.93	101.43	108.91
7-May-2003					109.43
8-May-2003					109.22
9-May-2003					108.27
10-May-2003					107.45
11-May-2003					107.87
12-May-2003					108.20
13-May-2003					108.69
14-May-2003					108.96
15-May-2003					108.44
16-May-2003					107.74
17-May-2003					98.29
18-May-2003					106.03
19-May-2003					107.44
20-May-2003					107.70
21-May-2003	104.90	108.67	103.81	104.12	107.42
22-May-2003	106.25	108.32	104.64	105.31	99.19
23-May-2003	106.91	105.55	104.30	104.90	99.43
24-May-2003	107.00	105.56	105.16	105.75	100.02
25-May-2003	104.99	104.31	104.50	104.71	99.35
26-May-2003	103.57	103.04	103.06	103.27	108.52
27-May-2003	105.19	103.62	103.74	104.36	108.95
28-May-2003	107.75	106.67	106.97	107.37	107.70
29-May-2003	108.23	107.19	107.34	107.52	105.43
30-May-2003	107.44	107.07	107.26	107.33	106.08
31-May-2003	106.99	107.05	106.73	106.92	106.93
1-Jun-2003	108.38	108.00	107.87	108.23	
2-Jun-2003	109.08	108.73	108.63	108.89	
3-Jun-2003	108.67	107.98	108.21	108.26	
4-Jun-2003	108.79	107.87	107.41	107.64	
5-Jun-2003	108.60	106.90	107.11	107.27	108.10
6-Jun-2003	108.13	106.75	106.85	107.03	108.22
7-Jun-2003	108.75	106.64	106.36	106.58	107.76
8-Jun-2003	107.43	106.57	106.49	106.65	105.40
9-Jun-2003	107.42	106.52	106.13	106.31	104.54
10-Jun-2003	105.93	106.12	105.39	105.51	104.65
11-Jun-2003	105.04	104.59	104.24	104.17	103.92
12-Jun-2003	105.57	104.88	104.25	104.51	105.06
13-Jun-2003	105.43	105.18	104.16	104.58	105.34
14-Jun-2003	104.18	105.78	103.40	103.63	105.75
15-Jun-2003	103.62	112.09	102.73	102.93	104.11
16-Jun-2003	104.99	106.65	103.08	103.40	103.33
17-Jun-2003	108.18	106.47	104.34	104.72	104.07
18-Jun-2003	106.07	109.13	105.03	105.12	104.86
Average	105.75	106.69	104.68	104.95	106.52
Count	41.00	29.00	41.00	41.00	51.00
Exceedance	0.00	0.00	0.00	0.00	0.00
% Exceedance	0.00	0.00	0.00	0.00	0.00

Table 6. Paired samples statistics for Forebay TDG Stations.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	MCQO	113.6469	55	2.82779	.38130
	MCQW	113.5330	55	2.76918	.37340
Pair 2	MCQO	113.6469	55	2.82779	.38130
	MCNDTD	111.9439	55	2.55346	.34431
Pair 3	MCQO	113.6469	55	2.82779	.38130
	MCNFBBRZP1	112.5329	55	2.70636	.36493
Pair 4	MCQO	113.6469	55	2.82779	.38130
	MCNFBFMSP1	113.2317	55	2.79599	.37701
Pair 5	MCQO	113.6469	55	2.82779	.38130
	MCNFBFMSP2	113.3864	55	2.68986	.36270
Pair 6	MCQW	113.5330	55	2.76918	.37340
	MCNDTD	111.9439	55	2.55346	.34431
Pair 7	MCQW	113.5330	55	2.76918	.37340
	MCNFBBRZP1	112.5329	55	2.70636	.36493
Pair 8	MCQW	113.5330	55	2.76918	.37340
	MCNFBFMSP1	113.2317	55	2.79599	.37701
Pair 9	MCQW	113.5330	55	2.76918	.37340
	MCNFBFMSP2	113.3864	55	2.68986	.36270
Pair 10	IHR	115.5976	54	3.09707	.42146
	IHRDTD	114.7643	54	2.89192	.39354
Pair 11	IHR	115.5976	54	3.09707	.42146
	IHRFBBRZ	115.2568	54	3.10908	.42309
Pair 12	IHR	115.5976	54	3.09707	.42146
	IHRFBFMS	115.1355	54	3.09051	.42056
Pair 13	IHR	117.0616	20	4.04229	.90388
	IHRFBNL	116.8062	20	4.05309	.90630
Pair 14	LMN	117.2425	27	4.93194	.94915
	LMNDTD	116.8380	27	4.71616	.90763
Pair 15	LMN	117.2425	27	4.93194	.94915
	LMNFBBRZ	116.8750	27	4.93932	.95057
Pair 16	LMN	117.2425	27	4.93194	.94915
	LMNFBFMS	116.7910	27	4.93428	.94960
Pair 17	LMN	117.2425	27	4.93194	.94915
	LMNFBNL	117.6738	27	5.03668	.96931
Pair 18	LGS	114.9259	28	5.66491	1.07057
	LGSFBBRZ	114.3262	28	5.67972	1.07337
Pair 19	LGS	114.9259	28	5.66491	1.07057
	LGSFBFMS	114.6811	28	5.60487	1.05922
Pair 20	LGS	114.9259	28	5.66491	1.07057
	LGSFBNL	113.9373	28	6.05994	1.14522
Pair 21	LWG	106.3443	32	1.91354	.33827
	LWGDTD	106.5247	32	1.81051	.32006
Pair 22	LWG	105.4903	48	2.07085	.29890
	LWGFBBRZP2	104.5124	48	1.91956	.27706
Pair 23	LWG	105.4903	48	2.07085	.29890
	LWGFBNL	104.7590	48	1.88759	.27245

Table 7. Paired Samples Tests for Forebay TDG Stations.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	MCQO - MCQW	.1139	1.04886	.14143	-.1696	.3975	.805	54	.424
Pair 2	MCQO - MCNDTD	1.7030	1.09191	.14723	1.4078	1.9982	11.567	54	.000
Pair 3	MCQO - MCNFBBRZP1	1.1140	1.19662	.16135	.7905	1.4374	6.904	54	.000
Pair 4	MCQO - MCNFBFMSP1	.4151	.17940	.02419	.3666	.4636	17.160	54	.000
Pair 5	MCQO - MCNFBFMSP2	.2605	1.04570	.14100	-.0222	.5432	1.847	54	.070
Pair 6	MCQW - MCNDTD	1.5891	1.00685	.13576	1.3169	1.8613	11.705	54	.000
Pair 7	MCQW - MCNFBBRZP1	1.0000	1.16804	.15750	.6843	1.3158	6.350	54	.000
Pair 8	MCQW - MCNFBFMSP1	.3012	1.06688	.14386	.0128	.5896	2.094	54	.041
Pair 9	MCQW - MCNFBFMSP2	.1466	.28676	.03867	.0691	.2241	3.791	54	.000
Pair 10	IHR - IHRDTD	.8333	.64707	.08805	.6567	1.0099	9.464	53	.000
Pair 11	IHR - IHRFBBRZ	.3408	.57525	.07828	.1838	.4978	4.354	53	.000
Pair 12	IHR - IHRFBFMS	.4622	.52236	.07108	.3196	.6048	6.502	53	.000
Pair 13	IHR - IHRFBNL	.2554	.32108	.07179	.1051	.4057	3.557	19	.002
Pair 14	LMN - LMNDTD	.4045	.45200	.08699	.2257	.5833	4.650	26	.000
Pair 15	LMN - LMNFBBRZ	.3675	.35539	.06840	.2269	.5081	5.373	26	.000
Pair 16	LMN - LMNFBFMS	.4515	.28775	.05538	.3377	.5653	8.153	26	.000
Pair 17	LMN - LMNFBNL	-.4313	.50819	.09780	-.6324	-.2303	-4.410	26	.000
Pair 18	LGS - LGSFBBRZ	.5996	.48168	.09103	.4129	.7864	6.587	27	.000
Pair 19	LGS - LGSFBFMS	.2448	.31520	.05957	.1226	.3670	4.109	27	.000
Pair 20	LGS - LGSFBNL	.9886	1.23306	.23303	.5105	1.4667	4.242	27	.000
Pair 21	LWG - LWGDTD	-.1804	2.14551	.37928	-.9539	.5932	-.476	31	.638
Pair 22	LWG - LWGFBBRZP2	.9780	.83551	.12060	.7354	1.2206	8.109	47	.000
Pair 23	LWG - LWGFBNL	.7314	.68185	.09842	.5334	.9293	7.431	47	.000

Decision Making Factors Related to FMS Stations

- The recommendations will result in more representative data that should improve uses such as project management for TDG as well as water quality compliance evaluations
- These changes will improve the stations ability to achieve all design purposes mentioned in the introduction of this report.
- The recommendations regarding the forebay FMS station location should be consistent across all projects.
- The changes will result in minimal impact on operation and maintenance of each station if each new station can be accessed in a similar fashion as used for the existing stations.

Future Considerations

- McNary Dam – reduce the number of stations to one and position it at 15 m deep either on the tip of the navigation lock guide wall or on a buoy located upstream of the powerhouse near the MCNFBBRZP1 station
- Ice Harbor Dam – relocate the fixed monitor to near the upstream tip of the navigation lock guide wall at 15 m
- Lower Monumental Dam – relocate the fixed monitor to near the upstream tip of the navigation lock guide wall at 15 m
- Little Goose Dam – relocate the fixed monitor to near the upstream tip of the navigation lock guide wall at 15 m
- Lower Granite Dam – reposition the existing instrument which is already located on the navigation lock guide wall to a depth of 15 m

2004 Transition Period

- Since the study conducted during 2003 was not exhaustive of every possible set of environmental conditions or variables that may be introduced by different water/weather years a transition period is recommended prior to any permanent relocations of stations.

- During this transition period testing should continue similar to the 2003 effort but only at the locations and depths described above.

- The alternate TDG stations should be limited to the navigation lock guide wall locations tested in 2003 for the Snake River projects and at McNary continue testing the upstream BRZ site and add a guide wall station further towards the upstream tip of the wall.

- The transition period would extend through 2004 and be followed with a reevaluation regarding permanent relocation of the forebay FMS stations.